COUNTY OF ROANOKE

STORMWATER MANAGEMENT DESIGN MANUAL

SEPTEMBER 11, 2007

Department of Community Development 5204 Bernard Drive Roanoke, Virginia 24018



COUNTY OF ROANOKE

STORMWATER MANAGEMENT DESIGN MANUAL

Chapter 1 – Introduction

1.1	Stormwater Management Goals	1-1
1.2	Contents of the Manual	
1.3	Authority	
1.4	Applicability	
1.5	Administration	
	1.5.1 General	
	1.5.2 Manual Amendments	
	1.5.3 Variances.	
	1.5.4 Appeal of Decisions	
1.6	Erosion and Sediment Control	1-5
1.7	Approval and Permits	1-5
	1.7.1 Local Approvals and Permits	1-5
	1.7.2 VSMP Permit	1-5
	1.7.3 Joint Permit Application	1-6
1.8	Reference Documents	1-6
1.9	Acronyms and Abbreviations	1-7
Cha	apter 2 Stormwater Management Plan Review and Aj	pproval
2.1	Overview of the Review and Approval Process	2-1
2.2	Concept Stormwater Management Plan Submittal	
2.3	Final Stormwater Management Plan Submittal	
2.4	Submittal of Stormwater Calculations	
2.5	Changes and Modifications to an Approved Plan	
	= • • • • • • • • • • • • • • • • • • •	

Chapter 3 Easements

3.1	Gene	ral	3-1
3.2	Drain	nage Easements	3-1
	3.2.1	Culverts and Storm Drains	3-2
	3.2.2	Open Channels	3-3
	3.2.3	Stormwater Management Facilities	3-3
3.3	Acces	ss Easements	3-4
3.4	Main	tenance of Easements	3-4
Appe	ndix 3A	A – Standard Easement Agreements	
Chaj	pter 4	Stormwater Hydrology	
4.1	Refer	ences	4-1
4.2	Desig	n Frequencies	4-1
	4.2.1	General	4-1
	4.2.2	Storm Drainage Systems	4-1
	4.2.3	Stormwater Management Facilities	4-2
4.3	Time	of Concentration (t _c) and Travel Time (T _t)	4-3
	4.3.1	General	
	4.3.2	Overland Flow	
	4.3.3	Shallow Concentrated Flow	
	4.3.4	Channelized Flow	
	4.3.5	Pipe Flow	
4.4		tion of Methodologies	
	4.4.1	General	
		Peak Discharge Methods for Design of Storm Drainage Systems	
	4.4.3	Hydrograph Methods for Design of Stormwater Management Faci	
4.5		odologies	
	4.5.1	Rational Method	
		Modified Rational Method	
	4.5.3	Anderson Method	
	4.5.4	SCS Method	
4.6		Development Conditions	
	4.6.1	Site Development	
	4.6.2	Redevelopment	
4.7	Drain	age Area Analysis	4-12
Appe	ndix 4B	A – Design Aids, From Chapter 6, VDOT Drainage Manual B – Design Aids, From Chapter 4, VA SWM Handbook C – Information from VDOT Hydraulic Design Advisories	

Chapter 5 Open Channels

		ences	
	Design	n Methodology and Criteria	5-1
	5.2.1	Major and Minor Channels	5-1
	5.2.2	Design Flow	5-1
	5.2.3	Hydrology	5-2
	5.2.4	Channel Hydraulics	5-2
	5.2.5	Channel Velocity	5-2
	5.2.6	Channel Slope	
	5.2.7	Cross Sectional Area	5-4
	5.2.8	Channel Lining.	5-5
	5.2.9	Freeboard Requirements	5-7
	5.2.10	Calculation of Depth of Flow at Bends and Curves	5-7
	5.2.11	Channel Location and Width Restrictions on Residential Lots	5-7
	Adequ	ate Channels	5-8
	Envir	onmental Considerations and Fishery Protection	5-9
	Maint	enance Requirements	5-9
	Flood	olain Studies	5-9
		– Aids for Open Channel Design, From Chapter 7, VDOT Dra Culverts	inage M
	pter 6 (•	
	pter 6 (Refero	Culverts ences	6-1
	pter 6 (Refero	Culverts	6-1 6-2
	pter 6 (Refere Design	Culverts ences n Methodology and Criteria	6-1 6-2 6-2
-	Refero Design 6.2.1	Culverts ences Methodology and Criteria Computation Methods	6-1 6-2 6-2
•	Refero Design 6.2.1 6.2.2	Culverts ences Methodology and Criteria Computation Methods Hydrology	6-16-26-26-2
	Refere Design 6.2.1 6.2.2 6.2.3	Culverts ences Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics	6-16-26-26-26-6
	Refere Design 6.2.1 6.2.2 6.2.3 6.2.4	Culverts ences n Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics Structural Design	6-16-26-26-26-6
	Refere Design 6.2.1 6.2.2 6.2.3 6.2.4 6.2.5	Culverts ences n Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics Structural Design Materials	6-16-26-26-6-66-6-66-6
	Refere Design 6.2.1 6.2.2 6.2.3 6.2.4 6.2.5 6.2.6	Culverts ences Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics Structural Design Materials Culvert Sizes	6-16-26-26-66-66-66-7
	Refere Design 6.2.1 6.2.2 6.2.3 6.2.4 6.2.5 6.2.6 6.2.7	Culverts In Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics Structural Design Materials Culvert Sizes End Conditions	6-16-26-26-66-66-66-76-8
	Reference	Culverts Pinces In Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics Structural Design Materials Culvert Sizes End Conditions Multiple Barrel Culverts	6-16-26-26-66-66-76-8
	Reference Design 6.2.1 6.2.2 6.2.3 6.2.4 6.2.5 6.2.6 6.2.7 6.2.8 6.2.9 6.2.10	Culverts ences Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics Structural Design Materials Culvert Sizes End Conditions Multiple Barrel Culverts Culvert Skew	6-16-26-26-66-66-66-76-86-8
	Reference	Culverts In Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics Structural Design Materials Culvert Sizes End Conditions Multiple Barrel Culverts Culvert Skew Buoyancy	6-16-26-26-66-66-76-86-86-8
	Reference	Culverts Pinces	6-16-26-26-66-66-76-86-86-86-86-9
	Reference Design 6.2.1 6.2.2 6.2.3 6.2.4 6.2.5 6.2.6 6.2.7 6.2.8 6.2.9 6.2.10 6.2.11 Install	Culverts Pinces Methodology and Criteria Computation Methods Hydrology Culvert Hydraulics Structural Design Materials Culvert Sizes End Conditions Multiple Barrel Culverts Culvert Skew Buoyancy Debris and Trash Racks	6-16-26-26-66-66-66-76-86-86-96-9
	Refere 6 (Design 6.2.1 6.2.2 6.2.3 6.2.4 6.2.5 6.2.6 6.2.7 6.2.8 6.2.9 6.2.10 6.2.11 Install 6.3.1 6.3.2	Culverts Pinces	6-16-26-26-66-66-76-86-86-96-9

Appendix 6A – Aids for Stormwater Culvert Design, From Chapter 8, VDOT Drainage Manual

Chapter 7 Storm Drains

7.1	References	
7.2	Design Methodology and Criteria	
	7.2.1 Computation Methods	
	7.2.2 Hydrology	
	7.2.3 Design Flows	
	7.2.4 Measures to Convey Stormwater Runoff to Inlets	
	7.2.5 Storm Drain Inlets	
	7.2.6 Storm Drain Pipes	
	7.2.7 Determination of Hydraulic Grade Line	
	7.2.8 100-Year Conditions	
	7.2.9 Materials	
	7.2.10 Structural Design	
7.3	Installation	
	7.3.1 Bedding Material	
	7.3.2 Backfill	
	7.3.3 Separation of Utilities	
7.4	Environmental Impacts	
7.5	Erosion Protection at Outfalls	
7.6	Maintenance Requirements	7-12
	endix 7B – Installation Procedures pter 8 Residential Lot Drainage (RESERVED)	
Cha	pter 9 Stormwater Detention	
	pter > Stormwater Detention	
9.1	References	9-2
	References	
	References Design Methodology and Criteria	9-2
	References Design Methodology and Criteria 9.2.1 Hydrology	
	References	
	References	
	References	
9.1 9.2	References Design Methodology and Criteria 9.2.1 Hydrology 9.2.2 Design Flows and Storage Volumes 9.2.3 Minimum Contributing Drainage Area 9.2.4 Detention Facility Locations 9.2.5 Basin Grading	9-2 9-2 9-2 9-2 9-2 9-2 9-3
	References	9-2 9-2 9-2 9-2 9-2 9-2 9-3 9-3
	References	9-2 9-2 9-2 9-2 9-2 9-2 9-3 9-4
	References Design Methodology and Criteria 9.2.1 Hydrology 9.2.2 Design Flows and Storage Volumes 9.2.3 Minimum Contributing Drainage Area 9.2.4 Detention Facility Locations 9.2.5 Basin Grading 9.2.6 Embankments and Emergency Spillways 9.2.7 Outlet Structures and Release Rates 9.2.9 Water Quality	9-2 9-2 9-2 9-2 9-2 9-2 9-3 9-4 9-4 9-6
	References	9-2 9-2 9-2 9-2 9-2 9-2 9-3 9-4 9-4 9-6

	Environmental Impacts
Chap	oter 10 Energy Dissipation
10.1 10.2	References
10.2	10.2.1 Outlet Velocity
	10.2.2 Erosion Control Stone 10-2
	10.2.3 Riprap Outlet Basins 10-2
	10.2.4 Baffled Outlets 10-3
	10.2.5 Energy Dissipator for Paved Areas
	10.2.6 Additional Energy Dissipators 10-4
10.3	Installation Requirements10-5
10.4	Easements
10.5	Environmental Impacts
10.6	Maintenance Requirements
	ndix 10B – Aids for Energy Dissipation Design, From VDOT Road and Bridge Standards ndix 10C – Energy Dissipation Design Schematics
Chap	oter 11 Stormwater Pollutant Removal Practices
Chap 11.1	oter 11 Stormwater Pollutant Removal Practices References
-	
11.1 11.2	References
11.1	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-2
11.1 11.2	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-5
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5Non Structural BMPs11-5
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5Non Structural BMPs11-5Structural BMPs11-6
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5Non Structural BMPs11-5Structural BMPs11-611.5.1 General Selection Criteria Information11-6
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5Non Structural BMPs11-5Structural BMPs11-611.5.1 General Selection Criteria Information11-611.5.2 Vegetated Filter Strip11-7
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5Non Structural BMPs11-5Structural BMPs11-611.5.1 General Selection Criteria Information11-611.5.2 Vegetated Filter Strip11-711.5.3 Grassed Swale11-9
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5Non Structural BMPs11-5Structural BMPs11-611.5.1 General Selection Criteria Information11-611.5.2 Vegetated Filter Strip11-711.5.3 Grassed Swale11-911.5.4 Constructed Wetlands11-12
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5Non Structural BMPs11-5Structural BMPs11-611.5.1 General Selection Criteria Information11-611.5.2 Vegetated Filter Strip11-711.5.3 Grassed Swale11-911.5.4 Constructed Wetlands11-1211.5.5 Extended Detention and Enhanced Extended Detention Ponds11-15
11.1 11.2 11.3	References11-1Stormwater Quality Requirements11-1Stormwater Quality Calculations11-211.3.1 BMP Selection Using Performance-Based Criteria11-211.3.2 BMP Selection Using Technology-Based Criteria11-511.3.3 Water Quality Volume (WQV)11-5Non Structural BMPs11-5Structural BMPs11-611.5.1 General Selection Criteria Information11-611.5.2 Vegetated Filter Strip11-711.5.3 Grassed Swale11-911.5.4 Constructed Wetlands11-12

	11.5.8 Infiltration Devices	11-24
	11.5.9 Sand Filter	11-29
	11.5.10 Oil Water Separator	
	11.5.11 Permeable Pavement	
	11.5.12 Manufactured BMP Systems	11-36
	·	
Appe	ndix 11A – Aids for Simple Method Calculations, From VA SWM Chapter 5 and Appendix 5D	Handbook,
	•	
Chap	pter 12 Environmentally Sensitive Areas	
12.1	References	12-1
12.2	Floodplains	
	12.2.1 Applicant Flood Study Requirements	
	12.2.2 Floodplain Delineation.	
12.3	Steep Slopes	12-5
	12.3.1 Development Restrictions	
	12.3.2 Design Standards	12-5
12.4	Stream Buffers	12-6
12.5	Critical Erosion Areas	12-6
12.6	Karst Geology	12-7
12.7	Stormwater Hot Spots	
	12.7.1 Design Restrictions	12-9
	12.7.2 Golf Course Development	12-9
Anne	ndix 12A – Design Aids, From Local Assistance Manual, Chesape	ake Ray Local
Appe	Assistance Department	akt Day Lucai
Chap	pter 13 Geotechnical Studies (RESERVED)	
Char	pter 14 Maintenance of Stormwater Management Facilit	ios
Спар	pter 14 Maintenance of Stormwater Management Pacint	103
14.1	Responsibility for Maintenance	
14.2	Maintenance Agreements	
14.3	Maintenance Program	
	14.3.1 Earthen Embankments	
	14.3.2 Principal Spillways	
	14.3.3 Emergency Spillway	
	14.3.4 Sediment Forebay	
	14.3.5 Landscaping	14-10
	14.3.6 Stormwater Detention and Retention Basins	
	14.3.7 Constructed Wetlands	
	14.3.8 Infiltration Practices	14-13

	14.3.9 Bioretention Filter	14-16
	14.3.10 Sand Filters	
	14.3.11 Grassed Swale	
	14.3.12 Vegetated Filter Strip	
	14.3.13 Manufactured BMP System	
	14.3.14 Conservation Areas	
	14.3.15 Underwater Detention Facilities	
	14.3.16 Oil Water Separator	
14.4	Additional Maintenance and Repair	
14.5	Inspection and Maintenance Records	
14.6	References	
Appe	ndix 14A – Maintenance Agreements ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia	Owners and Operate
Appe	ndix 14B – Maintaining Your BMP, A Guidebook for Private	Owners and Operate
Appe	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement	
Apper Chap	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia	15-1
Apper Chap	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement Construction Inspections	15-1
Apper Chap	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement Construction Inspections	
Apper Chap	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement Construction Inspections	
Apper Chap 15.1	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement Construction Inspections	
Apper Char 15.1	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement Construction Inspections	
Appen Chap 15.1	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement Construction Inspections	
Appen Chap 15.1	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement Construction Inspections	
Appen Chap 15.1	ndix 14B – Maintaining Your BMP, A Guidebook for Private in Northern Virginia oter 15 Inspection and Enforcement Construction Inspections	

Appendix 15A – Inspection Forms

Chapter 1 - Introduction

1.1 Stormwater Management Goals

As land is developed and woodlands and pastures are converted to more intensive commercial and residential uses, the increase in impervious surfaces (pavements and buildings) cause adverse effects including:

- Increased flooding
- Increased erosion and deposition of sediment in streams
- Increased property damage due to flooding, erosion, or deposition
- Less base flow in streams due to less groundwater recharge
- Increased runoff of pollutants (nutrients, sediment, bacteria, oil)
- Decreased stream biodiversity

The County of Roanoke stormwater management goals are to minimize and mitigate these adverse effects of land development by implementing effective stormwater management Best Management Practices as required by the County Code.

The County of Roanoke Stormwater Management Design Manual, hereafter called the Design Manual, was developed to provide guidance to developers, property owners, and design professionals and to assist them in meeting the Stormwater Management Ordinance requirements. It serves as a local supplement to, and not as a replacement for, existing State guidance manuals that address proper stormwater management design techniques. These manuals include:

- Virginia Department of Conservation and Recreation Stormwater Management Handbook
- Virginia Department of Transportation Drainage Manual
- Virginia Department of Conservation and Recreation Erosion and Sediment Control Handbook

The use of the Design Manual and generally accepted references should ensure that standard, acceptable design practices are used for stormwater management designs. However, the County of Roanoke encourages the development and use of innovative stormwater management practices that meet the requirements of the Stormwater Management Ordinance and that can be demonstrated to perform equivalent to the standards set forth in this Design Manual.

1.2 Contents of the Manual

The Design Manual is divided into 15 chapters. An overview of each chapter is presented below.

<u>Chapter 1 – Introduction</u>. Chapter 1 presents the general background and purpose behind the Design Manual. The chapter documents the goals of the program, the applicable requirements for stormwater management, variance requests and the administration of the program.

<u>Chapter 2 – Stormwater Management Plan Review and Approval</u>. Chapter 2 presents the process that the applicant and the County of Roanoke follow to assure that the requirements of the stormwater management program and the Stormwater Management Ordinance are met. The chapter covers the conception, construction, submittal, review, and approval of the stormwater management plan as a part of the overall Development Plan package.

<u>Chapter 3 – Easements</u>. Chapter 3 establishes the requirements for easements for stormwater management facilities and storm drainage systems.

<u>Chapter 4 – Stormwater Hydrology</u>. Chapter 4 documents the hydrologic design practices used to establish design flows necessary to design storm drainage systems and stormwater management facilities. Calculation design methodologies and event frequencies are established.

<u>Chapter 5 – Open Channels</u>. Chapter 5 presents the requirements for open channel hydraulics, including cross section requirements, side slopes, widths, slopes, channel linings, and calculation methods.

<u>Chapter 6 – Culverts</u>. Chapter 6 presents the requirements for culverts, including materials, slopes, headwater and tailwater limitations, and design calculation methods.

<u>Chapter 7 – Storm Drains</u>. Chapter 7 presents the requirements for storm drains, including storm drain piping sizes, and lengths, and storm drain inlet hydraulics.

<u>Chapter 8 – Residential Lot Drainage</u>. (RESERVED)

<u>Chapter 9 – Detention and Retention Storage</u>. Chapter 9 presents requirements and design criteria for stormwater storage facilities. Design criteria include location, sizing requirements, site access, release rates, and spillway requirements. The use of stormwater facilities as best management practices for use in stormwater quality design is covered in Chapter 11.

<u>Chapter 10 – Energy Dissipation</u>. Chapter 10 includes the requirements for velocity and energy reduction devices at the discharge from storm drains, culverts, open channels, and other stormwater management systems. Energy dissipation is required to prevent excessive velocities and erosion in downstream channels.

<u>Chapter 11 – Stormwater Pollutant Removal Practices</u>. Chapter 11 presents the design and calculation requirements for best management practices (BMPs). The section includes BMP selection, structural BMP requirements and limitations, and encouragement in the use of low-impact design and non-structural BMP practices.

<u>Chapter 12 – Environmentally Sensitive Areas</u>. Chapter 12 presents requirements for development of environmentally sensitive areas including floodplains, stream buffers, steep slopes, erodible soils, and stormwater pollutant hot spots.

Chapter 13 – Geotechnical Studies. (RESERVED)

<u>Chapter 14 – Maintenance of Stormwater Management Facilities.</u> Chapter 14 presents the requirements for establishing a maintenance program for stormwater management facilities, and the establishment of a maintenance agreement to assure that stormwater management facilities are properly maintained.

<u>Chapter 15 – Inspection and Enforcement</u>. Chapter 15 presents the inspection and enforcement procedures to ensure that construction of stormwater management facilities comply with the approved plans and are properly maintained post-construction.

1.3 Authority

The Design Manual provides the policies and procedures that implement the provisions of the County Code as they pertain to stormwater management, including storm drainage.

In the event that any part of this Design Manual is held to be illegal or void, this shall not have the effect of making illegal or void the Design Manual in its entirety, or any section thereof, which shall remain effective.

1.4 Applicability

The requirements of this Design Manual apply to all land disturbance activities that require a site development plan submittal, stormwater management plan submittal, or zoning, building, or land disturbance permit, except as exempted below.

The following activities are exempt from the stormwater performance criteria set by the Stormwater Management Ordinance and are not required to submit a stormwater management plan:

- Permitted surface or deep mining operations and projects, oil and gas operations, and projects conducted under the provisions of Title 45.1 of the Clean Water Act;
- Tilling, planting, or harvesting of agricultural, horticultural, or silvicultural crops;
- Single-family residences separately built and not part of a subdivision, including additions or modifications to existing single-family detached residential structures.
- Land disturbance activities that disturb less than 5,000 square feet of land area.

• Linear development projects, provided that (i) less than 5,000 square feet of land will be disturbed per outfall, (ii) the resulting increase in the peak flow discharge from a 10-year frequency, 24-hour storm event is less than 0.5 cubic feet per second (cfs), and (iii) there are no existing or anticipated flooding or erosion problems downstream of the discharge point as determined by the County of Roanoke.

The design criteria for stormwater management facilities and storm drainage systems apply to both public and private facilities unless the Design Manual specifically states otherwise.

Any additions, extensions, and/or modifications to development which were previously exempt shall provide stormwater management for the entire combined development when the acreage limitations are exceeded.

Portions of this Design Manual apply to maintenance and repair of stormwater management facilities and other best management practices after construction is completed.

1.5 Administration

1.5.1 General

The policies and procedures contained within this Design Manual shall be administered by the County of Roanoke, Director of Community Development (Director), or designee, or by the administrator otherwise identified in this Design Manual.

1.5.2 Manual Amendments

This Design Manual will be periodically amended, as necessary to address:

- Changes in technology
- Changes in accepted construction practices
- Changes in Federal and/or State requirements
- Items that require clarification to avoid confusion
- Development issues that potentially impact public health, safety and welfare

Amendments to this Design Manual will be posted on the County website, www.roanokecountyva.gov, and will become effective on the date listed on the website. It is the manual user's responsibility to check the website and verify that they have the latest requirements.

1.5.3 Variances

Requests for variance of any provisions of this Design Manual shall be made in writing to the County of Roanoke, Director of Community Development. The variance request shall clearly identify the Design Manual provision that is desired to be modified; the justification to support the issuance of a variance, and the alternative measures that are proposed to meet the intent of the Design Manual. All requests for a variance will receive a written response outlining the reasons for approval, or denial, within 30 days of receipt of all information requested by the Director. In reviewing the request, the Director shall closely examine the proposed development and evaluate the variance request based on the conditions set forth in the County of Roanoke Code, Stormwater Management Ordinance, Section XX-4.1.

1.5.4 Appeal of Decisions

Appeals of decisions may be filed in accordance with the procedures provided in the County of Roanoke Code, Stormwater Management Ordinance, Section XX-4.2.

1.6 Erosion and Sediment Control

Effective erosion and sediment control during land development and redevelopment activities is important to support the goals of minimizing and mitigating adverse effects and to allow the proper long-term operation of many stormwater management facilities.

Erosion and sediment control shall comply with the Erosion and Sediment Control Ordinance and the requirements of the Virginia Erosion and Sediment Control Handbook, Current Edition, as amended.

1.7 Approvals and Permits

The applicant is responsible for acquiring all required approvals and permits.

1.7.1 Local Approvals and Permits

The review and approval of stormwater management plans shall be an integral part of the overall review of site plans. For preparation and submittal of stormwater management plans and the approval process, see Chapter 2.

1.7.2 VSMP Permit

As of January 2005, the Virginia Department of Environmental Quality (DEQ) no longer administered the Virginia Pollution Discharge Elimination System (VPDES) construction permit program. These permits are administered by the Virginia Department of Conservation and Recreation's (DCR) Virginia Stormwater Management Program (VSMP). DCR is responsible for the issuance, denial, revocation, termination and enforcement of VSMP permits for the control of stormwater discharges from land disturbing activities regulated under the Virginia Stormwater Management Program.

COUNTY OF ROANOKE 9/11/07

INTRODUCTION

Owners and operators of land disturbing activities equal to or larger than one acre are required to apply for registration coverage under the General Permit for Discharges of Stormwater from Construction Activities.

For additional information, permit application and checklist, and fee registration forms, visit the DCR website: http://www.dcr.virginia.gov/sw/vsmp.

1.7.3. Joint Permit Application

Wetlands and streams are protected under several Federal and State programs. Whenever jurisdictional wetlands or streams are impacted by land disturbing activities, a Joint Permit Application must be completed and filed with the Virginia Marine Resources Commission (VMRC). VMRC will distribute the joint permit application to The U.S. Army Corps of Engineers (COE) and the Virginia Department of Environmental Quality (DEQ). The COE and DEQ will consult with other Federal and State agencies in processing the permit application. Upon receipt of an acceptable application the following permits may be issued:

- COE Federal Section 404 Permit
- DEQ Water Protection Permit
- VMRC Permit

1.8 Reference Documents

This Design Manual was written to serve as a supplement to existing state design manuals that address proper stormwater management design techniques, and not to replace them. In the case of a contradiction or conflict, the more stringent requirement shall apply.

The requirements of the following state design manuals and standards are incorporated into this Design Manual by reference.

- <u>Virginia Stormwater Management Handbook, Volumes I and II</u>, prepared by the Virginia Department of Conservation and Recreation, dated 1999 or latest version, as amended. Hereafter throughout this Design Manual referred to as the VA SWM Handbook.
- <u>Virginia Department of Transportation Drainage Manual</u>, prepared by the Hydraulics Section of the Virginia Department of Transportation, dated 2002 or latest version, as amended. Hereafter throughout this Design Manual referred to as the VDOT Drainage Manual

• <u>Virginia Department of Transportation Road and Bridge Standards, Volumes I and II,</u> prepared by the Virginia Department of Transportation, dated 2001 or latest version, as amended. Hereafter throughout this Design Manual referred to as the VDOT Standards.

- <u>Virginia Department of Transportation Road and Bridge Specifications</u>, prepared by the Virginia Department of Transportation, dated 2002 or latest version, as amended. Hereafter throughout this Design Manual referred to as the VDOT Specifications.
- <u>Virginia Erosion and Sediment Control Handbook</u>, prepared by the Virginia Department of Conservation and Recreation, dated 1992 or latest version, as amended. Hereafter throughout this Design Manual referred to as the VA E&SC Handbook.

In addition, the following documents provide guidance on low-impact development and non-structural best management practices, which applicants are encouraged to practice when developing or redeveloping sites.

- <u>Design Manual for Use of Bioretention in Stormwater Management</u>, Prince George's County, Maryland, prepared by Engineering Technologies Associates, Inc., dated 1993.
- Better Site Design, An Assessment of the Better Site Design Principles for Communities Implementing Virginia's Chesapeake Bay Preservation Act, prepared by Center for Watershed Protection, Inc., no date.
- <u>Low-Impact Development Design Strategies</u>, An Integrated Design Approach, prepared by Prince George's County, Maryland, dated 1999.

1.9 Acronyms and Abbreviations

For clarification, the following is a listing of abbreviations, and acronyms used in stormwater management and throughout this Design Manual.

A – Drainage area, acres (stormwater hydrology)

A – Cross section area, square feet (open channel or pipe hydraulics)

B – VDOT rainfall coefficient, no units (stormwater hydrology)

BMP – Best management practice

C – Runoff coefficient, no units (stormwater hydrology)

C_f – Saturation factor, no units (stormwater hydrology)

CMP – Corrugated metal pipe

CN – Curve Number (stormwater hydrology)

COE – U.S. Army Corps of Engineers

D – VDOT rainfall coefficient, no units (stormwater hydrology)

DCR - Virginia Department of Conservation and Recreation

D_e – Critical duration, minutes (stormwater hydrology)

DEQ - Virginia Department of Environmental Quality

COUNTY OF ROANOKE

E – VDOT rainfall coefficient, no units (stormwater hydrology)

FEMA – Federal Emergency Management Agency

g – Gravity coefficient, 32.2 feet/s²

H – Height or depth of water, feet

 H_f , H_i , H_m , H_o , H_Δ – Head losses in piping and structures, feet (storm drain hydraulics)

HDPE – High density polyethylene

HGL – Hydraulic grade line

I – Rainfall intensity, inches per hour (stormwater hydrology)

I_{post} – Post-development impervious cover, percentage (water quality Simple Method calculation)

I_{existing} – Existing impervious cover, percentage (water quality Simple Method calculation)

K, K_i, K_o – Head loss coefficients for piping, no units

L_{pre} – Pre-development pollutant loading, pounds per year (water quality Simple Method calculation)

L_{post} – Post-development pollutant loading, pounds per year (water quality Simple Method calculation)

MS4 – Municipal Separate Storm Sewer System

n – Manning's equation roughness coefficient, no units (open channel and pipe hydraulics)

NFIP – National Flood Insurance Program

Q – Stormwater flow, gallons per minute (gpm) or cubic feet per second (cfs)

R – Hydraulic radius, feet (open channel hydraulics)

r_c – Stream bend radius, center, feet (open channel hydraulics)

r_i – Stream bend radius, inside bank, feet (open channel hydraulics)

r_o – Stream bend radius, outside bank, feet (open channel hydraulics)

S – Slope, feet per feet (open channel or pipe hydraulics)

SCS – Soil Conservation Service

t_c – Time of concentration, hours (stormwater hydrology)

 T_p – Time to peak flow, hours (stormwater hydrology)

 T_r – Time to recede, hours (stormwater hydrology)

 T_t – Travel time, hours (stormwater hydrology)

V, V_i, V_o – Velocity, feet per second (open channel and pipe hydraulics)

VA E&SC Handbook – Virginia Erosion and Sediment Control Handbook, latest version, as amended

VA SWM Handbook – Virginia Stormwater Management Handbook, latest version, as amended

VDOT – Virginia Department of Transportation

VDOT Drainage Manual – Virginia Department of Transportation, Drainage Manual, latest version, as amended

VDOT Specifications – Virginia Department of Transportation, Road and Bridge Specifications, latest version, as amended

VDOT Standards – Virginia Department of Transportation, Road and Bridge Standards, latest version, as amended

VMRC - Virginia Marine Resources Commission

VSMP - Virginia Stormwater Management Program, as administered by DCR

 ΔZ = Difference in water surface elevation from the inside curve to the outside curve of an open channel, feet (open channel hydraulics)

COUNTY OF ROANOKE

Chapter 2 – Stormwater Management Plan Review and Approval

In order to maintain the character and integrity of neighborhoods, to promote excellence of development, to prevent undue traffic and environmental hazards, and to encourage the most harmonious development and use of land, a site development plan is required for commercial and residential development and shall be submitted to the County of Roanoke's Development Review Coordinator.

These plans will be distributed to the appropriate departments and divisions for review and approval. When required, the applicant is also responsible for submittals to the Virginia Department of Environmental Quality, the Virginia Department of Conservation and Recreation, and other applicable regulatory agencies for their review and approval. When applicable, all of these entities must approve the site development plan prior to the issuance of any permits for all types of developments as required by the Zoning Ordinance and the Erosion and Sediment Control Ordinance.

In cases where jurisdictional waters exist on the proposed site, the applicant may need to obtain approvals and/or permits from any or all of the following agencies: the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, the Virginia Department of Environmental Quality, the Virginia Department of Conservation and Recreation, and the Virginia Marine Resource Commission.

2.1 Overview of the Review and Approval Process

No application for land development, land use conversion, or land disturbance will be approved unless it includes a stormwater management plan, detailing how runoff and associated water quality impacts resulting from the activity will be controlled or managed. The stormwater management plan will be submitted as a part of the site development plan. No building, zoning, grading, site development, or land disturbance permit will be issued without first meeting the requirements of the Stormwater Management Ordinance, as shown in the approved stormwater management plan.

The submittal, review, and approval of site development plans, including concept stormwater management plans and final stormwater management plans will follow the Roanoke County Land Development Procedures. This document is available from the County of Roanoke Development Review Coordinator.

2.2 Concept Stormwater Management Plan Submittal

A concept site development plan, including a concept stormwater management plan, is required by the County of Roanoke when the proposed development meets any of the conditions set forth in the Roanoke County Land Development Procedures.

2.3 Final Stormwater Management Plan Submittal

An approved site development plan, including a final stormwater management design, is required prior to issuance of a Land Disturbance Permit, Building Permit or a Zoning Permit.

The final stormwater management plan shall be appropriately sealed and signed by a professional in adherence to all minimum standards and requirements pertaining to the practice of that profession in accordance with Chapter 4 (§ 54.1-400 et seq.) of Title 54.1 of the Code of Virginia and attendant regulations.

Copies of the stormwater management plan will be reviewed by the County of Roanoke Engineering Division. In addition to Roanoke County's review, the Virginia Department of Transportation, Virginia Department of Environmental Quality, and Virginia Department of Conservation and Recreation may also review the site development plan with the final stormwater management plan, as appropriate. Plans for review by these entities must be submitted directly to them, when required.

Following the submission of the site development plan, including the final stormwater management design, a review meeting will be scheduled with all reviewing entities, the design engineer, and the applicant to allow the opportunity to discuss plans and comments with the plan review team.

2.4 Submittal of Stormwater Calculations

Calculations shall be submitted to the County of Roanoke supporting the stormwater management and storm drainage design. Calculations shall be well organized and coordinated with the design to allow for efficient review by the County. Calculations shall be bound together in a booklet or stapled together, depending on the number of pages. Calculations shall follow the following general format:

- Cover Sheet The cover sheet shall contain the project name, property tax parcel(s) number(s), applicant's name, design professional's name, calculations date, and (for final calculations) the seal and signature of the design professional.
- Table of Contents A table of contents shall be provided where the calculations exceeds 25 pages, or where appropriate to assist the reviewer in locating information in the calculations.
- Introduction A general description of the project providing information to assist the reviewer in understanding the nature and scope of the project and of the storm drainage and stormwater management facilities that are proposed.

- Criteria and Methodology A listing of the basic design criteria (e.g. 10/2 and 25/10 year peak flow control, no increase in phosphorous, and no flooding during the 100-year storm) and of the methodologies that the calculations will follow to demonstrate that the basic design criteria are met.
- References A listing of references that are used in the calculations
- Assumptions A listing of all assumptions, and justification of the assumptions that are used in the calculations.
- Analysis The body of the calculations clearly labeled as to what storm water management facility or storm drainage system the calculations are for. The calculations shall be step-by-step to ensure that a reviewer that is not familiar with the project can follow the progression of the calculations. If computer printouts are provided highlight the input and output information and ensure that the input information is clearly supported in the calculations, and that the output is properly evaluated in the summary and conclusions. All calculation parameters must be fully supported and documented and include the design storm frequency, intensity and duration, times of concentration, soil curve numbers or runoff coefficients; calculations identifying pre-and post-development peak runoff rates and total runoff volumes for each watershed area, infiltration rates (where applicable), culvert, storm drain, and open channel capacities, flow velocities, data on the increase in rate and volume of runoff for the specified design storms, pre- and post-development phosphorous runoff rates and all other calculations needed to support the proposed design.
- Summary and Conclusions A summary of the results, preferably in tabular or chart form for each storm drain system and stormwater management facility to indicate that the land disturbing project meets the requirements of the Design Manual and any conclusions.
- Appendices and Attachments Any supporting information such as drainage area maps, soils maps, U.S.G.S. quadrangle maps, design nomographs, and computer printouts.

Calculations that are not well organized and coordinated with the design shall be rejected and the submittal shall not be reviewed until proper calculations are submitted.

2.5 Changes and Modifications to an Approved Plan

Changes to an approved subdivision or site plan, including an approved stormwater management plan, must be submitted for review to the County of Roanoke Development Review Coordinator. The County of Roanoke, upon receipt of the resubmittal of an approved development plan, shall review and approve or disapprove the resubmitted plan according to the

STORMWATER MANAGEMENT PLAN REVIEW AND APPROVAL

CHAPTER 2

Roanoke County Land Development Procedures. Approval or disapproval of the resubmitted plan shall be made in writing to the applicant.

Any use, arrangement, location, or construction not in compliance with the approved plan is a violation of the County Code.

Chapter 3 - Easements

3.1 General

Easements may be required as a part of a subdivision plat or site plan review. The purpose of this section is to provide policy, procedures, and guidelines for establishing easements for storm drainage and stormwater management systems. Easements may grant certain rights and privileges to the County or a public entity such as VDOT for public easements, or to specific landowners in the case of private easements.

Proposed easements will be shown conceptually on preliminary site plans. The easements will be in final form on the submitted stormwater management plan and will be consistent with the design on final plats and site plans.

Easements will be dimensioned to allow them to be located in the field by providing dimensional ties to property corners. Where easements are aligned with property lines, offset dimensions will be provided. Verification of easement location will be required as a part of the as-built requirements. If drainage or stormwater management improvements are found to have been constructed outside of the easement; then, the permittee will be responsible for vacating the original easement and recording a new easement, in the proper location, at the permittee's expense.

Easements shall not split property lines. Where an open channel or storm drain system runs parallel to a property line, it shall be offset from the property line an adequate amount so that the easement is totally contained on the property that contains the open channel or storm drain and not split onto the adjacent property.

3.2 Drainage Easements

Drainage easements giving the County or a public entity such as VDOT the right to discharge stormwater runoff onto private property is required for all public storm drainage systems and stormwater management facilities that are located on private property. This includes open channels, culverts, inlets, storm drains, stormwater management basins, and other best management practices that are owned, operated, and maintained by the County or a public entity such as VDOT. Public storm drainage systems are used to convey stormwater drainage from public property, public right-of-way, or another public storm drainage system through private property. Once the stormwater is discharged into a perennial or intermittent stream, or is otherwise managed, a public drainage easement is not required. Public stormwater management facilities are used to provide appropriate stormwater management for stormwater runoff generated by land development on public property. Examples of situations where a public drainage easement is required include:

 Concentrated stormwater runoff from a public school discharging to private property, including any open channels leaving the property or any storm drains leaving the property.

- Concentrated stormwater runoff from public streets and open channels or storm drains from the public street right-of-way which passes onto any private property.
- A stormwater management facility that provides regional stormwater management and is located on private property.

Drainage easements giving a private party the right to discharge concentrated stormwater runoff onto downstream private property is required whenever connection is made to a downstream private storm drainage system.

No buildings, foundations, structures, or walls, not associated with the storm drainage system or stormwater management facility shall be located within a drainage easement. In addition, easements that contain open channels shall not be obstructed by fences or vegetation.

Storm drainage easements shall not be located within 10 feet of the rear wall of any individ ingle-family residential structure.

Underground utility lines and structures shall be kept at least 5-feet horizontal from drainage pipes, structures, and channels, except at utility crossings. Utility crossings at drainage easements shall be at as near 90-degress as possible.

Where a storm drainage system terminates or starts short of a property line, adequate drainage easements shall be dedicated to allow for maintenance and future extension of the system ugh the property. Drainage easements shall not split property lines.

3.2.1 Culverts and Storm Drains

The minimum width of drainage easements for culverts and storm drains shall be as follows:

Pipe Size (width)	Minimum Easement Width -
33" and smaller	20 feet
36" – 42"	25 feet
48" – 60"	30 feet
66" – 78"	35 feet

^{*}Minimum width given above is for installations with depths of cover of 10-feet or less (measured at the top of pipe). For each additional 5-feet of cover over 10-feet (rounded up), the minimum easement width will be increased by 10-feet.

For pipes that are wider than given in the table above, and for installations that result in minimum easement widths greater than 50-feet due to installation depths, the minimum easement width shall be set by the County based on the width requirements to access the pipe in the future for repair.

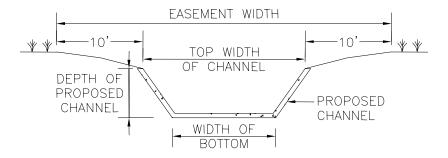
Drainage easements at the inlet and outlet of all culverts and storm drain inlets shall include the areas inundated by the headwater during the 100-year storm. The easement shall extend a minimum of 10 feet from culvert inlets and outlets and storm drain inlets to allow for maintenance access. Where steep slopes and/or deep fills exist, additional easement area may be required to allow for proper access.

Storm drain easements shall cross private driveways at perpendicular angles to the extent practical.

3.2.2 Open Channels

The width of the drainage easement required is dependent on the top width of the channel as indicated in Figure 3-1.

Figure 3-1
Easement Width for Open Channels



3.2.3 Stormwater Management Facilities

Private drainage easements shall be provided for all structures, pond area, embankments, inlet and outlet channels, and access and working areas necessary to inspect, maintain, and repair the facilities. The 100-year flooding area of all stormwater basins or other holding structures, plus a minimum distance of 20-feet all around the facility, shall be contained within the drainage easement area. Additional area will be provided if necessary for the proper maintenance of the facility.

3.3 Access Easements

Access easements giving the County the right to access private property for the purpose of inspecting, and if necessary to maintain or repair private stormwater management facilities is required for all private stormwater management facilities. This includes stormwater management basins, filter strips, bioretention trenches, underground detention areas, and all other BMP's.

All structures, pond areas, embankments, inlet and outlet channels, and access and working areas necessary to inspect, maintain, and repair the facilities shall be included in access easements. The 100-year flooding area of all stormwater basins or other holding structures shall be contained within the access easement area.

In addition, all stormwater management facilities shall contain a minimum 20-foot working area around all stormwater management basins and a minimum 10-foot working area around all other BMPs and an access easement connecting to a public road. Depending on the size and location of the stormwater management facility and the size and length of the storm sewer system, more than one vehicle accessible access easement connecting to a public road may be required.

All stormwater structures and BMPs shall be accessible by vehicle. Areas within an access easement that are intended to be vehicle accessible shall have a maximum slope of 10 percent for unpaved surfaces and 18 percent for paved surfaces. The vehicle access shall be a minimum of 12 feet in width. The minimum width for an access easement shall be 20 feet.

All access easements shall connect to a public road or right of way.

3.4 Maintenance of Easements

Ownership of land within easements shall remain with the property owner. The property owner shall have the responsibility of maintaining the easement areas free of any obstructions or use that would interfere with the rights or privileges granted by the property owner.

The property owner shall not alter the existing ground elevations or in any way redirect or obstruct stormwater flow. Any alterations to easements resulting in obstruction or redirection of flow will be returned to existing elevations immediately at the cost of the property owner.

EASEMENTS APPENDIX 3A

APPENDIX 3A

STANDARD EASEMENT AGREEMENTS

County of Roanoke – Permanent Drainage Easement Agreement

EASEMENTS APPENDIX 3A

Exemption Claimed: Grantee is exempted from recordation taxes and fees pursuant to § 58.1-811A(3), Code of Virginia.
Prepared By:
Tax Map No.: Property Owners:
THIS DEED OF EASEMENT, made this day of, 20, by and between AND husband and wife (whether one or more, "Grantor") and the BOARD OF SUPERVISORS OF ROANOKE COUNTY, VIRGINIA ("Grantee").
WITNESSETH:
That for and in consideration of the sum of One Dollar (\$1.00), paid in hand at and with the execution and delivery of this Deed of Easement, and other good and valuable consideration, the receipt, adequacy and sufficiency of which is hereby acknowledged, the Grantor does hereby GRANT and CONVEY with General Warranty and Modern English Covenants of Title unto the Grantee, its successors and assigns, the following described easement, to-wit:
A perpetual RIGHT and EASEMENT, approximatelyfeet in width, to construct, operate, maintain, inspect and repair or replace a drainage system and related improvements including slope(s), if applicable, together with the right of ingress and egress thereto from a public road, upon, over, under, and across a tract or parcel of land belonging to the Grantor, acquired by deed dated and recorded in the Clerk's Office of the Circuit Court of Roanoke, Virginia, in Deed Book, page, and designated on the Roanoke County Land Records as Tax Map No (the "Property"). The location of said easement is more particularly described on the plat attached hereto as "Exhibit A" and by this reference made a part hereof (the "Plat"), and shown traversing as shown on Exhibit A.
The Grantee agrees to restore and repair any actual damage to Grantor's Property which

The Grantee agrees to restore and repair any actual damage to Grantor's Property which may be directly caused by the construction, reconstruction, or maintenance of said project except as hereinafter provided. The Grantor agrees that the Grantee will not be expected to restore the Property to the identical original condition, but rather as near thereto as is practicable, and that the Grantor will cooperate with the Grantee in effectuating such restoration.

It is expressly agreed between the parties hereto that the Grantee and its agents shall have the right to inspect the easement herein granted and to cut, clear, and remove all undergrowth, obstructions, or improvements lying within, upon, or adjacent to said easement, that in any way endanger or interfere with the proper use of the same. The Grantor covenants that no building or structure shall be erected upon or within the easement herein granted or placed in such location as to render the said easement inaccessible. In the event that this covenant is violated, the

COUNTY OF ROANOKE 9/11/07

EASEMENTS

EASEMENTS APPENDIX 3A

Grantee shall not be obligated to repair, replace, or otherwise be responsible for such improvements if damaged or removed.

The Grantor acknowledges that the plans for the aforesaid project as they affect the Property have been fully explained to the Grantor or Grantor's authorized representative. The fixtures, facilities, lines, utilities, and any other improvements placed upon, under, or across the Property by the Grantee shall remain the property of the Grantee. The easement herein granted is in addition to, and not in lieu of, any easement or right-of-way now in existence or which may be acquired in the future.

The Grantor covenants and aggress for themselves, and for their heirs, successors, successors in title, executors, legal representatives, and assigns that the consideration aforementioned and the covenants herein shall be in lieu of any and all claims to compensation and damages by reason of the location, construction, operation, maintenance, or reconstruction of or within the easement herein granted.

The grant and provision of this Deed of Easement shall constitute a covenant running with the land for the benefit of the Grantee, its successors and assigns forever to have and hold unto the Grantee, its successors and assigns forever.

Elmer C. Hodge, County Administrator of Roanoke County, Virginia, hereby j execution of this instrument to signify the acceptance by said Board of Supervisors of estate conveyed herein pursuant to Ordinance No. adopted by the		
Supervisors of Roanoke County, Virginia, on the	day of	
WITNESS the following signatures and seals:		
GRANTOR:		
		(SEAL)
		(SEAL)

Chapter 4 - Stormwater Hydrology

Stormwater hydrology defines the means and methods to calculating stormwater runoff from a designated area. This section documents the hydrologic practices used to establish design flows necessary to prepare the required stormwater peak flow and storage calculations.

4.1 References

Except where more stringent requirements are presented in this Design Manual, stormwater hydrology shall comply with VDOT and DCR requirements. The primary design references are:

- VDOT Drainage Manual
- VA SWM Handbook

4.2 Design Frequencies

4.2.1 General

Design frequencies shall be selected consistent with good engineering practice and economics. The design frequency requirements given in this Design Manual are minimum, specific conditions may dictate that less frequent design frequency should be used.

4.2.2 Storm Drainage Systems

Storm drainage systems consist of open channels, culverts, and storm drains. Designs shall be based on the following minimum design storm frequencies:

Open Channels:

Minor Channel Capacity

Minor Channel Protective Lining	
(Drainage Area 5 acres or less)	2-year
Minor Channel Protective Lining	
(Drainage Area over 5 acres)	10-year
Major Channel Capacity	100-year
Major Channel Protective Lining	10-year
(100-year if potential for catastrophic failure	e)

Culverts:

Storm

Principal Arterial Roads Other Roads	25-year 10-year
Drains	10-year

10-year

Storm drainage designs must also convey water to stormwater management facilities that attenuate peak flows during the 25-year event. Conveyance during the 25-year event may be a combination of piped flow and overland flow as long as the overland flow does not cause flooding of structures or unsafe conditions.

Additionally, all storm drainage designs for open channels, culverts, and storm drains shall be checked for the 100-year flow condition where there is the possibility of flooding residences, commercial or industrial buildings, overtopping primary roads, experiencing significant economic loss, or catastrophic failure. Where justified by the consequences of failure, the minimum design frequency shall be increased.

4.2.3 Stormwater Management Facilities

Certain stormwater management facilities temporarily store a portion of stormwater runoff to mitigate increases to stormwater runoff peak flows and volumes due to the effects of land development. Water quality control is required as well and is discussed in Chapter 11.

A. Stormwater Management Quantity

Stormwater management facilities that control water quantity for new development shall be designed to meet the following criteria:

- The 25-year post development peak rate of runoff from the development site shall not exceed the 10-year pre-developed peak rate of runoff; and
- The 10-year post-developed peak rate of runoff from the development site shall not exceed the 2-year pre-developed peak rate of runoff.

These two criteria shall be considered individually. Where an adequate channel is not present downstream from the development, additional requirements may be applied as described in Chapter 5.

B. Stormwater Management for Conservation Easements

If land within an overall land disturbing activity is placed into a conservation easement, where the land will remain or be returned to a wooded condition, then the following applies:

• Land placed within a conservation easement are assumed to be woods in good condition for post developed conditions, irregardless of their current condition. This reflects the goal that land within the conservation will not be disturbed and will become wooded through planting or natural succession.

• Lands placed within a conservation easement are assumed to have no increase in stormwater volume as a result of the land disturbing activity. For calculation purposes, the post development peak rate of runoff shall equal the pre-developed peak rate for the 25-year and 10-year design storms.

To clarify when a land disturbing activity includes area within a conservation easement, the water quantity calculations shall be as follows:

Contributing	Quantity Requirement		
Drainage Area	Post Development Peak Flow Pre Development Peal	k Flow	
DA	$Q_{DA Post 25} = Q_{DA Pre 10}$		
	$Q_{DA Post 10} = Q_{DA Pre 2}$		
CA	$Q_{CA Post 25} = Q_{CA Pre 25}$		
	$Q_{CA Post 10} = Q_{CA Pre 10}$		
Total	$Q_{TOTAL Post 25} = Q_{DA Pre 10} + Q_{CA Pre 2}$.5	
(DA + CA)	$Q_{TOTAL Post 10} = Q_{DA Pre 2} + Q_{CA Pre 10}$)	

DA – Development Area which equals the total project area minus the Conservation Area

CA – Conservation Area

Total – Total Project Area which equals the Development Area plus the Conservation Area

Q_{DA Post 25} (typical) – Peak flow from the Development Area for post development 25year design storm conditions

For requirements of conservation easements, see Chapter 3.

C. Reserved for Future Use

4.3 Time of Concentration (t_c) and Travel Time (T_t)

4.3.1 General

Time of Concentration (t_c) is the length of time required for a drop of water to travel from the most hydraulically distant point in the watershed, or subwatershed to the point of analysis. Travel Time (T_t) is the length of time required for that same drop of water to travel from the study point at the bottom of the sub-watershed to the study point at the bottom of the whole watershed. The travel time is descriptive of the sub-watershed by providing its location relative to the study point of the entire watershed. Therefore Time of Concentration is the summation of Travel Time values for the various consecutive flow segments.

Travel Time and Time of Concentration generally consist of four flow types- overland flow, shallow concentrated flow, channelized flow, and pipe systems. The following methods shall be used to determine the flow and velocity for the various conditions; however, the results shall be reviewed for reasonableness and the results shall be revised if needed to provide a reasonable velocity and flow time that will best represent the study area.

When designing a drainage system, the flow path is not necessarily the same before and after land disturbing activities have been completed. Therefore, the travel time path shall be reflective of the actual conditions both before and after the land disturbing activities.

In some cases, runoff from a portion of the drainage area that is highly impervious may result in a greater peak discharge than would occur if the entire area were considered. In this case, adjustments can be made to the drainage area by disregarding those areas where flow time is too slow to add to the peak discharge.

To prevent small drainage areas from skewing the time of concentration calculation results, when establishing sub drainage areas for analysis, the largest sub drainage area shall be no greater than 5 times the area of the smallest sub drainage area.

4.3.2 Overland Flow

Overland flow is flow that occurs at the upper end of a watershed, where flow is not concentrated and there are no channels. The length of overland flow shall be reflective of actual conditions and shall normally be no greater than 150 feet.

Where the overland flow does not contain any slopes exceeding 5% <u>AND</u> if the soils are not designated as highly erodible, a maximum length of overland flow of 200 feet may be used. Highly erodible soils are designated as United States Department of Agriculture Natural Resources Conservation Service land capability classification (LCC) classes IIIe, IVe, VI, VII, or VIII or having an erodibility index greater than or equal to 8.

Overland flow shall be calculated using the Seelye chart contained in the Appendix 4A.

4.3.3 Shallow Concentrated Flow

Shallow concentrated flow is the flow that occurs when minor rivulets form just downstream from the overland flow. The maximum allowable length for shallow concentrated flow shall be 1000 feet. Shallow concentrated flow shall be calculated using the Overland Flow Velocity Chart from HEC-19 or by using the nomograph entitled "Time of Concentration of Small Drainage Basins," developed by P.Z. Kirpich. Copies of the chart and nomograph are contained in Appendix 4A.

4.3.4 Channelized Flow

Channelized flow occurs where stormwater flow converges in gullies, ditches, and natural or man-made water conveyances, including storm drain pipes and culverts. Channelized flow shall be calculated by use of the nomograph entitled "Time of Concentration of Small Drainage Basins," developed by P.Z. Kirpich. A copy of the nomograph is contained in Appendix 4A.

4.3.5 Pipe Flow

Pipe flow is the flow that occurs through culverts and storm drains. Use full-flow pipe velocities, unless it may be demonstrated that the pipe will operate at partial full conditions. If it can be shown that the pipe will operate at partial full conditions, then the partial full pipe velocity may be used.

Design of flow through culverts is presented in Chapter 6.

Design of flow in storm drain systems is presented in Chapter 7.

4.4 Selection of Methodologies

4.4.1 General

There are a variety of widely used hydrologic methodologies. Each has its strengths and weaknesses. In the interest of standardizing hydrologic calculations, the following methodologies will be used for all projects, unless a variance is granted. A variance will only be granted if it may be demonstrated that good engineering practice dictates the use of another method.

4.4.2 Peak Discharge Methods for Design of Storm Drainage Systems

The rational method may be used to design storm drainage systems for drainage areas up to 200 acres.

The Anderson method may be used for drainage areas over 200 acres and less than 10 square miles.

The SCS method may be used for drainage areas up to 10 square miles.

For drainage areas greater than 10 square miles, calculations shall be performed using at least two separate methods as described in the VDOT Drainage Manual (SCS method, regression equations, and/or stream gage data). The design peak flow shall be selected based on a professional evaluation of the results of the various methods.

4.4.3 Hydrograph Methods for Design of Stormwater Management Facilities

The modified rational method may be used to design stormwater management facilities where drainage areas are less than 20 acres and times of concentration are less than 20 minutes.

The SCS method may be used in all cases. The SCS method must be used where drainage areas are 20 acres or greater, or where times of concentration are 20 minutes or longer.

4.5 Methodologies

Following is an abbreviated discussion of each method. Refer to the VDOT Drainage Manual for a more complete discussion of the Rational Methods and Anderson Method and the VA SWM Handbook for a more complete discussion of the SCS Method.

4.5.1 Rational Method

A. General

The Rational Method is expressed as:

$$Q = C_fCIA$$

Where:

Q = Peak flow rate of runoff, cubic feet per second (cfs)

 C_f = Saturation factor

C = Runoff coefficient representing a ratio of runoff to rainfall (dimensionless)

I = Average rainfall intensity for a duration equal to the time of concentration for a selected return period, inches per hour (in/hr)

A = Drainage area contributing to the design location, acres (ac)

B. Saturation Factor

The saturation factor (C_f) is an adjustment factor for modifying the runoff coefficient (C) for storms that are less frequent than a 10-year recurrence interval. The product of C_f and C should not be greater than 1.0.

Recurrence Interval (Years)	$\underline{\mathbf{C}}_{\underline{\mathbf{f}}}$	
2, 5, and 10	1.0	
25	1.1	
50	1.2	
100	1.25	

Where the product of C_f and C is greater than 1.0, use 1.0.

C. Runoff Coefficient

The runoff coefficient (C) is a variable of the Rational Method that requires significant judgment and understanding for proper selection. A range of C-values for a given land use is given in Appendix 4A.

The coefficient must account for all the factors affecting the relation of peak flow to average rainfall intensity other than area adjustment. Some of these factors include land slope, condition of cover, and antecedent moisture condition.

As the slope of the drainage basin increases, the selected C-value should also increase. The lower range of C-values should be used where the majority of the slopes are less than 2-percent. The average range of C-values should be used where the majority of slopes are 2 to 5-percent. The higher range of C-values should be used where the majority of the slopes are greater than 5-percent.

The higher range of C-values should be used in clayey and other less pervious soil areas.

It is often necessary to develop composite C-values based on the different land uses and other factors in a drainage basin. The C-values for residential areas, given in the charts, do not include impervious areas associated with roadways. The effects of roadways must be added.

D. Average Rainfall Intensity

Rainfall intensity (I) shall be determined by utilizing VDOT Hydraulic Design Advisory HDA 05-03, adopted June 21, 2005. A tabulation of rainfall intensities for selected durations, using this publication, has been included in Appendix 4C.

For storm durations that are not included in the table in Appendix 4C, rainfall intensities shall be determined using the following formula:

$$I = B / (t_c + D)^E$$
 where:

I = Rainfall intensity for a given recurrence interval, in inches per hour

t_c = Watershed time of concentration (assumed to equal the storm duration), in minutes

B,D,E = As taken from HDA 05-03 table for Roanoke based on the designated storm frequency.

Storm Recurrence	В	D	Е
Interval			
2 year	47.62	11.50	0.85
5 year	47.08	10.75	0.79
10 year	47.73	10.75	0.75
25 year	38.78	8.50	0.67
50 year	34.84	7.25	0.62
100 year	29.06	5.25	0.55

E. Drainage Area

Drainage area (A) is measured in acres and is determined from evaluating a topographic map of the area.

4.5.2 Modified Rational Method

A. General

The Modified Rational Method is a means to generate hydrographs for small drainage areas. The parameters for the calculation are the same as the Rational Method, except that a series of average rainfall intensities from different storms with the same frequency and different durations are computed. The hydrograph from the critical duration storm is used to design stormwater management facilities.

The Modified Rational Method recognizes that the duration of a storm is often longer than the time of concentration. This longer duration storm, even though it produces a lower peak Q, can produce a larger volume of runoff than the storm duration equal to the actual time of concentration of the drainage area. In order to ensure the proper design of stormwater management facilities, the runoff for the critical storm duration shall be used.

B. Hydrograph Assumptions

The hydrograph generated by the Modified Rational Method is based on the following assumptions:

• Time of Concentration (t_c) = Time to Peak (T_p) = Time to Recede (T_r)

- The length of the critical duration storm (D_e) is from 0 minutes until the time of selected duration.
- The rate of runoff is 0 at time 0 minutes. The rate of runoff increases linearly with time until the peak rate of runoff is reached at time T_p .
- The peak rate of runoff is maintained from time T_p until the duration of the storm (D_e). The rate of runoff then decreases to 0 at time D_e plus T_r.
- The peak rate of runoff is based on the average rainfall intensity (I) for the given storm duration.

C. Critical Duration Storm

The critical duration storm is the storm of a given frequency that has a duration that yields the greatest volume of storage in a stormwater management facility when the storm hydrograph is routed through the stormwater management facility. The critical duration storm may be estimated for preliminary purposes; however, the actual critical duration storm must be determined by routing the various duration storm hydrographs through the stormwater management facility and demonstrating which storm duration gives the greatest volume of storage.

4.5.3 Anderson Method

The Anderson Method may be used for computing peak flows for storms of selected frequency. This method is described in VDOT, Hydraulic Design Advisory (HDA) 05-05. A copy of this advisory is included in Appendix 4C.

4.5.4 SCS Method

A. General

The SCS Method may be used for computing peak flows and hydrographs for storms of selected return frequencies. This approach considers the time distribution of the rainfall, the initial rainfall losses to interception and depression storage and an infiltration rate that decreases during the course of a storm. The information required to use the SCS Method to determine the peak rate of runoff, or to develop a runoff hydrograph is:

- 24-hour total rainfall, and rainfall distribution type;
- Time of Concentration (t_c) in minutes;
- Curve Number (CN), which is determined by Cover Types and Hydrologic Soils Groups; and

• Drainage Area (A) in acres.

If the drainage basin is over 20 acres, or if it contains areas of different land uses, the drainage basin should be divided into sub-basins. Each sub-basin should have similar land uses. When sub-basins are used, the following information is required to use the SCS Method to determine the peak rate of runoff, or to develop a runoff hydrograph:

- 24-hour total rainfall, and rainfall distribution type;
- Time of Concentration (t_c) in minutes for each sub-basin;
- Curve Number (CN), which is determined by Cover Types and Hydrologic Soils Groups, for each sub-basin;
- Drainage Area (A) in acres, for each sub-basin; and
- Travel Time (T_t) of the flow from each sub-basin as it flows through downstream sub-basins.

If the SCS Method is being used to design a stormwater management facility, the following additional information is required to rout the runoff hydrograph through the facility and to generate an outflow hydrograph:

- Elevation Storage Relationship
- Elevation Discharge Relationship
- B. 24-hour Rainfall and Distribution

The 24-hour rainfall is determined by consulting the map for the appropriate return frequency located in Appendix 4B. The rainfall distribution type for the Roanoke Valley is Type II

C. Curve Number

The SCS method uses a combination of soil conditions and land use (ground cover) to assign a runoff factor to an area. These runoff factors, or runoff curve numbers (CN), indicate the runoff potential of an area. The CN requires significant judgment and understanding for proper selection. A table containing CNs for various cover types and soils conditions is contained in Appendix 4B.

When calculating existing rates of runoff (pre-construction), assume that all cover types are in good hydrologic condition.

Hydrologic Soils Groups include types A, B, C, and D, with type A being the most permeable and type D the least permeable. Appendix 4B includes a listing of most soil names with their respective hydrologic soils types. Soils maps for the Roanoke Valley may be obtained by referring to http://soils.usda.gov/.

D. Drainage Area

Drainage areas for each sub-basin should be identified on an appropriate topographic map. The USGS quadrangle maps are often appropriate to delineate drainage areas that extend beyond the site development area.

E. Elevation – Storage Relationship

When runoff hydrographs are being routed through a stormwater management facility, the relationship between the elevation (or depth) of stored water in the facility and storage volume needs to be known and input into the calculation. Often this information is obtained by determining the pond area bounded by contour lines on a grading plan. Enough data pairs (elevation – storage) must be provided to properly model conditions at transition points.

F. Elevation – Discharge Relationship

When runoff hydrographs are being routed through a stormwater management facility, the relationship between the elevation (or depth) of stored water in the facility and the discharge flow rate from the facility needs to be known and input into the calculation. The development of this relationship requires an understanding of the design conditions and underlying hydraulic principles. The hydraulic principals and equations governing the discharge rate will often change several times at varying elevations. These include weir flow, orifice flow, culvert inlet control, culvert outlet control, open channel flow, and possible effects from downstream backwater.

4.6 Pre Development Conditions

4.6.1 Site Development

Pre-development hydrologic calculations for land disturbing activities shall consider the site conditions that have existed for the 5-year period before the site plan application and shall use the site condition that results in the lowest peak rate of runoff, and the lowest impervious area. As an example, if a site was originally wooded and was cleared and converted to grassland 4-years before the submission of the site plan, then the pre-development condition used in the calculations would be wooded in good condition.

4.6.2 Redevelopment

Pre-development hydrologic calculations for redevelopment projects shall consider the site conditions that have existed for the 5-year period before the site plan application and may use the site condition that results in the highest peak rate of runoff, and the highest impervious area.

As an example, if a site originally contained a building and was 60-percent impervious and the building was demolished and removed 4-years before the submission of the site plan changing the impervious percentage to 40-percent, then the pre-development condition used in the calculations for both water quantity and quality may be based on the 60-percent impervious area.

4.7 Drainage Area Analysis

When determining the stormwater management requirements for quantity control, an analysis of the pre- and post-development site conditions must be conducted. Per DCR Technical Bulletin #1, individual lots or parcels in a residential, industrial, or commercial development shall not be considered to be separate development projects. The drainage area analysis shall reflect the ultimate development conditions of the property where the land disturbing activity is being permitted.

To prevent the undersizing of stormwater management components, upstream properties conditions shall be considered in the drainage area analysis. Stream channel and improvements to any conveyance system shall be analyzed based on the ultimate development conditions. Design of drainage infrastructure shall be based on current zoning development and the associated anticipated densities of impervious area.

When a project site contains or is divided by multiple drainage areas, stormwater management of each drainage area must be addressed separately. Over detention of one flow is not an effective solution to achieving water quantity goals. Improving the channel immediately downstream is not effective in controlling the actual flow release from the site being developed, nor does it reduce the impact of the flow on properties further downstream.

APPENDIX 4A

DESIGN AIDS

FROM CHAPTER 6, VDOT DRAINAGE MANUAL

Overland Flow Nomagraph – Seelye

Overland Flow Velocity

Time of Concentration for Small Drainage Basins – Kirpich

Average Velocities for Estimating Travel Time for Shallow Concentrated Flow

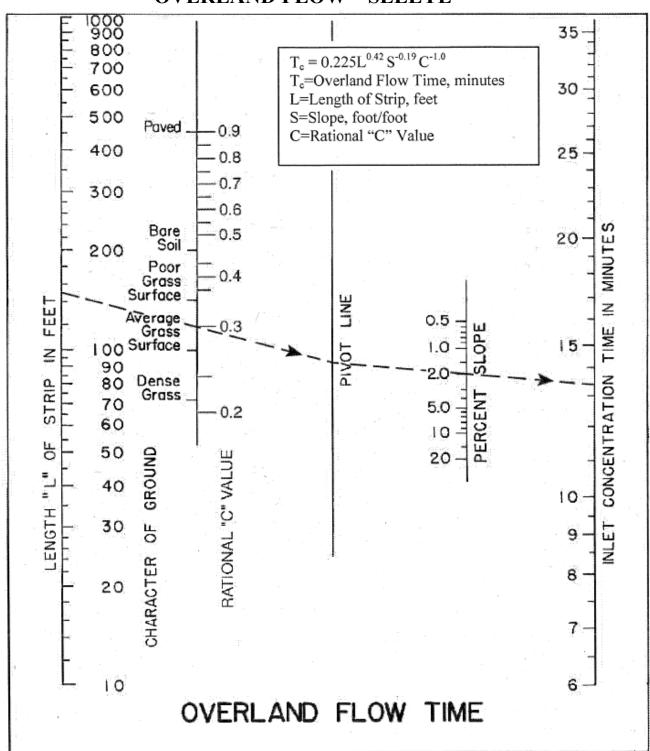
Rational Method Runoff Coefficients

Runoff Curve Numbers for Urban Areas

Runoff Curve Numbers for Cultivated Agricultural Areas

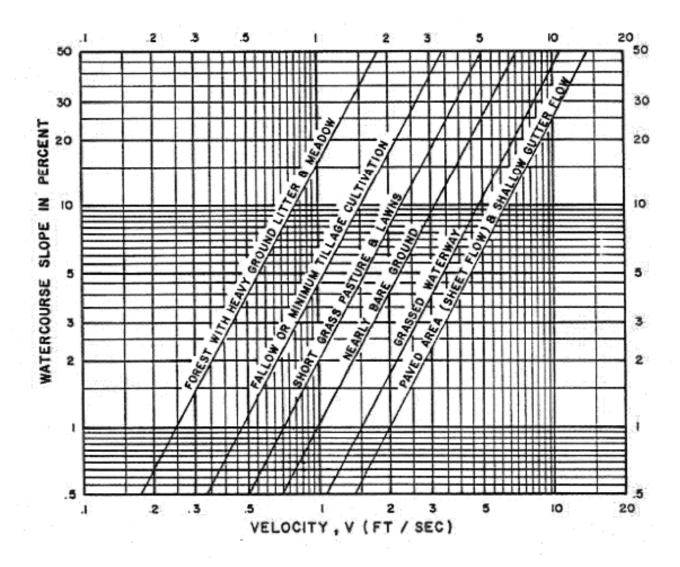
Runoff Curve Numbers for Other Agricultural Areas

OVERLAND FLOW - SEELYE

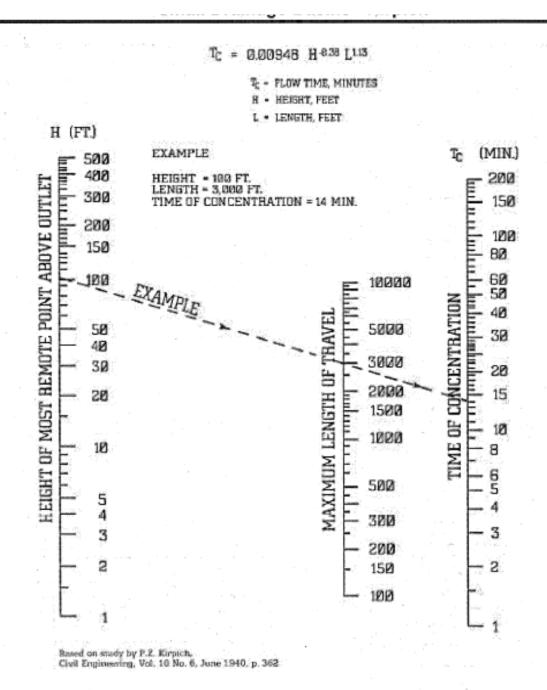


REPRINTED WITH PERMISSION FROM "DATA BOOK FOR CIVIL ENGINEERS" VOL. I-DESIGN 2mg EDITION (1951) BY E.E. SEELYE

OVERLAND FLOW VELOCITY

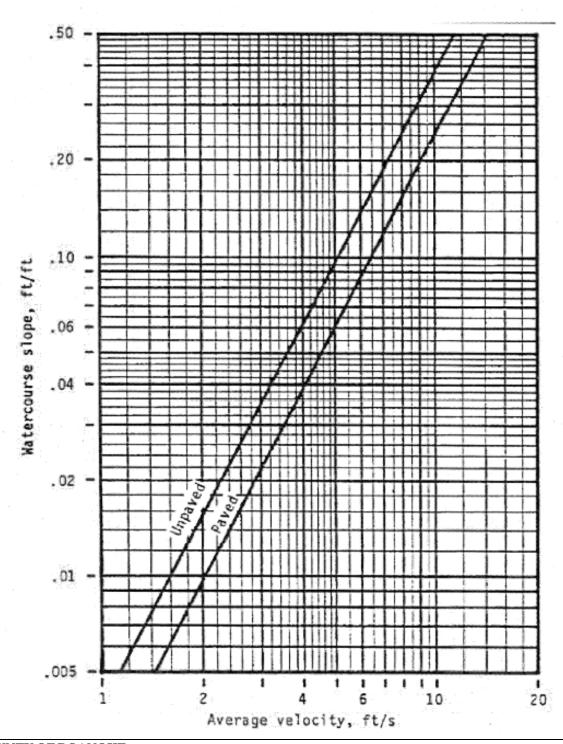


TIME OF CONCENTRATION - KIRPICH



TIME OF CONCENTRATION OF SMALL DRAINAGE BASINS

AVERAGE VELOCITIES FOR ESTIMATING TRAVEL TIME FOR SHALLOW CONCENTRATED FLOW



RATIONAL METHOD – RUNOFF COEFFICIENTS

Description of Area	Runoff Coefficients
Business: Industrial and Commercial	0.80-0.90
Apartments and Townhomes	0.65-0.75
Schools	0.50-0.60
Residential - Lots 10,000 sf	0.40-0.50
- Lots 12,000 sf	0.40-0.45
- Lots 17,000 sf	0.35-0.45
- Lots ≥ ½ acre	0.30-0.40
Parks, Cemeteries, and Unimproved Areas	0.20-0.35
Paved and Roof Areas	0.90
Cultivated Areas	0.50-0.70
Pasture	0.35-0.45
Lawns	0.25-0.35
Forest	0.20-0.30
Steep Grass (2:1) *	0.40-0.70
Shoulder and Ditch Areas *	0.35-0.50

Comments:

- 1. The lowest range of runoff coefficients may be used for flat areas (areas where the majority of the grades and slopes are 2% and less).
- 2. The average range of runoff coefficients should be used for intermediate areas (areas where the majority of the grades and slopes are from 2% to 5%).
- 3. The highest range of runoff coefficients shall be used for steep areas (areas where the majority of the grades are greater than 5%), for cluster areas, and for development in clay soil areas.
- * Lower runoff coefficients should be used for permanent or established conditions (post-construction), i.e. sizing stormwater management basins.
- * Higher runoff coefficients should be used to design roadside ditch linings (construction). The design considers the ditch lining as not yet established.

RUNOFF CURVE NUMBERS FOR URBAN AREAS

	S	oil (Frou	p
	A	В	C	D
Cover type and hydrologic condition				
Open space (lawns, parks, golf courses, cemetaries):				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50% to 75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways (excluding right-of-way)	98	98	98	98
Streets and roads:				
Paved; curbs and storm drains (excluding right-of-way)	98	98	98	98
Paved; open ditches (including right-of-way)	83	89	92	93
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Urban districts:				
Commercial and business (85% average impervious area)	89	92	94	95
Industrial (72% average impervious area)	81	88	91	93
Residential districts by average lot size:				
0.10 or less, town houses (65% average impervious area)	77	85	90	92
¹ / ₄ acre (38% average impervious area)	61	75	83	87
1/3 acre (30% average impervious area)	57	72	81	86
½ acre (25% average impervious area)	54	70	80	85
1 acre (20% average impervious area)	51	68	79	84
2 acre (12% average impervious area)	46	65	77	82
Developing urban areas:				
Newly graded areas (pervious areas only, no vegetation)	77	86	91	94

RUNOFF CURVE NUMBERS FOR CULTIVATED AGRICULTURAL AREAS

Cover	Treatment	Hydrologic	,	Soil (Grouj	p
type		condition	A	В	C	D
Fallow	Bare soil		77	86	91	94
	Crop residue	Poor	76	85	90	93
	Cover (CR)	Good	74	83	88	90
Row Crops	Straight Row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR and CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C and CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & Terraced	Poor	66	74	80	82
	(C & T)	Good	62	71	78	81
	C&T and CR	Poor	65	73	79	81
		Good	61	70	77	80
Small Grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR and CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C and CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T and CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded	SR	Poor	66	77	85	89
or broadcast		Good	58	72	81	85
Legumes or	С	Poor	64	75	83	85
rotation		Good	55	69	78	83
Meadow	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Comments:

- 1. Crop residue cover (CR) applies only if residue is on at least 5% of the surface throughtout the year.
- 2. Poor = Factors impair infiltration and tend to increase runoff
- 3. Good = Factors encourage average and better than average infiltration and tend to decrease runoff.

RUNOFF CURVE NUMBERS FOR OTHER AGRICULTURAL AREAS

Cover	Hydrologic	S	oil C	Frou	p
type	condition	A	В	C	D
Pasture ¹ , grassland, or range-	Poor	68	79	86	89
continuous forage for grazing	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass,		30	58	71	78
protected from grazing and					
generally mowed for hay					
Brush ² – brush-weed-grass mixture	Poor	48	67	77	83
with brush as the major element	Fair	35	56	70	77
	Good	30	48	65	73
Woods – grass combination	Poor	57	73	82	86
(orchard or tree farm)	Fair	43	65	76	82
	Good	32	58	72	79
Woods ³	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads – buildings, lanes,		59	74	92	86
driveways, and surrounding lots					

Comments:

1. Pasture Poor < 50% ground cover or heavily grazed with no mulch Fair 50% to 75% ground cover and not heavily grazed Good > 75% ground cover and lightly or only occasionally grazed

2. Brush Poor < 50% ground cover Fair 50% to 75% ground cover Good > 75% ground cover

3. Woods Poor – Forest litter, small trees and brush are destroyed by heavy grazing or regular burning

Fair – Woods grazed but not burned, and some forest litter covers the soil Good – Woods protected from grazing, litter and brush adequately cover soil

R HYDROLOGY APPENDIX 4B

APPENDIX 4B

DESIGN AIDS

FROM CHAPTER 4, VA SWM HANDBOOK

Rational Equation Coefficients for SCS Hydrological Soil Groups, Urban Land Uses

Rational Equation Coefficients for SCS Hydrological Soil Groups, Rural and Agricultural Uses

Roughness Coefficient "n" for Manning Equation – Sheet Flow

Roughness Coefficient "n" for Manning Equation – Pipe Flow

Roughness Coefficient "n" for Manning Equation – Constructed Channels

Roughness Coefficient "n" for Manning Equation – Natural Stream Channels

Hydrologic Soils Names in Virginia (7 sheets)

RATIONAL EQUATION COEFFICIENTS FOR SCS HYDROLOGIC SOIL GROUPS (A, B, C, D) URBAN LAND USES

	STORM FREQUENCIES OF LESS THAN 25 YEARS												
Land Use	Hydrologic		Hydrologic Soil Group/Slope										
	condition		A			В			C		D		
		0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Paved Areas and Impervious Surfaces		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Open Space, Lawns, etc	Good	0.08	0.12	0.15	0.11	0.16	0.21	0.14	0.19	0.24	0.20	0.24	0.28
Industrial		0.67	0.68	0.68	0.68	0.68	0.69	0.68	0.69	0.69	0.69	0.69	0.70
Commercial		0.71	0.71	0.72	0.71	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Residential		0.25	0.28	0.31	0.27	0.30	0.35	0.30	0.33	0.38	0.33	0.36	0.42
Lot size 1/8 acre													
Lot size ¼ acre		0.22	0.26	0.29	0.24	0.29	0.33	0.27	0.31	0.36	0.30	0.34	0.40
Lot size 1/3 acre		0.19	0.23	0.26	0.22	0.26	0.30	0.25	0.29	0.34	0.28	0.32	0.39
Lot size ½ acre		0.16	0.20	0.24	0.19	0.23	0.28	0.22	0.27	0.32	0.26	0.30	0.37
Lot size 1 acre		0.14	0.19	0.22	0.17	0.21	0.26	0.20	0.25	0.31	0.24	0.29	0.35

RATIONAL EQUATION COEFFICIENTS FOR SCS HYDROLOGIC SOIL GROUPS (A, B, C, D) RURAL AND AGRICULTURAL LAND USES

	STORM FREQUENCIES OF LESS THAN 25 YEARS													
Land Use	Treatment/	Hydrologic					Hydrolo			p/Slop	e			
	Practice	condition		A			В			С		D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture	Non-contoured	Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
or Range														
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21
Fallow	Straight Row		0.41	0.48	0.53	0.60	0.66	0.71	0.72	0.78	0.82	0.84	0.88	0.91
	Straight Row	Good	0.24	0.30	0.35	0.43	0.48	0.52	0.61	0.65	0.68	0.73	0.76	0.78
Row Crops	Contoured	Good	0.21	0.26	0.30	0.41	0.45	0.49	0.55	0.59	0.63	0.63	0.66	0.68
Kow Crops	Contoured and	Good	0.20	0.24	0.27	0.31	0.35	0.39	0.45	0.48	0.51	0.55	0.58	0.60
	Terraced													
	Straight Row	Good	0.23	0.26	0.29	0.42	0.45	0.48	0.57	0.60	0.62	0.71	0.73	0.75
Small Grain	Contoured	Good	0.17	0.22	0.27	0.33	0.38	0.42	0.54	0.58	0.61	0.62	0.65	0.67
Sinan Grain	Contoured and	Good	0.16	0.20	0.24	0.31	0.35	0.38	0.45	0.48	0.50	0.55	0.58	0.60
	Terraced													
	Straight Row	Good	0.15	0.19	0.23	0.31	0.35	0.38	0.55	0.58	0.60	0.63	0.65	0.66
Closed-seeded Legumes	Contoured	Good	0.14	0.18	0.21	0.30	0.34	0.37	0.45	0.48	0.51	0.58	0.60	0.61
Or Rotation Meadow	Contoured and	Good	0.07	0.10	0.13	0.28	0.32	0.35	0.44	0.47	0.49	0.52	0.54	0.56
	Terraced													

ROUGHNESS COEFFICIENT "n" FOR MANNING EQUATION – SHEET FLOW

Surface Description	n
Smooth Surfaces (Concrete,	0.011
Asphalt, Gravel, or Bare Soil)	
Fallow (no residue)	0.05
Cultivated Soils:	
Residue Cover < 20%	0.06
Residue Cover > 20%	0.17
Grass: Short Grass Prairie Dense Grasses Bermuda Grass	0.15 0.24 0.41
Range (Natural)	0.13
Woods:	0.40
Light Underbrush	0.40
Dense Underbrush	0.80

ROUGHNESS COEFFICIENT "n" FOR MANNING EQUATION – PIPE FLOW

Material	"n" R	Range
Material	From	To
Coated Cast Iron	0.010	0.014
Uncoated Cast Iron	0.011	0.015
Vitrified Sewer Pipe	0.010	0.017
Concrete Pipe	0.010	0.017
Common Clay Drainage Tile	0.011	0.017
Corrugated Metal (2 2/3 x ½)	0.023	0.026
Corrugated Metal (3x1 and 6x1)	0.026	0.029
Corrugated Metal (6x2 structural plate)	0.030	0.033

ROUGHNESS COEFFICIENT "n" FOR MANNING EQUATION – CONSTRUCTED CHANNEL

Lining Material	"n" F	Range
Lining Waterian	From	To
Concrete Lined	0.012	0.016
Cement Rubble	0.017	0.025
Earth, Straight and Uniform	0.017	0.022
Rock Cuts, Smooth and Uniform	0.025	0.033
Rock Cuts, Jagged and Irregular	0.035	0.045
Winding, Sluggish Canals	0.022	0.027
Dredged Earth Channels	0.025	0.030
Canals with Rough Stony Beds, Weeds on Earth Banks	0.025	0.035
Earth Bottom, Rubble Sides	0.028	0.033
Small Grass Channels: Long Grass – 13" Short Grass – 3"	0.042 0.034	

ROUGHNESS COEFFICIENT "n" FOR MANNING EQUATION – NATURAL STREAM CHANNEL

Channel Lining	"n" R	Range
	From	To
Clean, Straight Bank, Full Stage No Rifts or Deep Pools	0.025	0.030
2. Same as #1, Some Weeds and Stones	0.030	0.035
3. Winding, Some Pools and Shoals, Clean	0.033	0.040
4. Same as #3, Lower Stages, More Ineffective Slope and Sections	0.040	0.050
5. Same as #3, Some Weeds and Stones	0.035	0.045
6. Same as #4, Stony Sections	0.045	0.055
7. Sluggish River Reaches, Rather Weedy with Very Deep Pools	0.050	0.070
8. Very Reedy Reaches	0.075	0.125

Soil Name	Hydgrp	Soil Name	Hydgrp	Soil Name	Hydgrp
APPOMATTOX	В	AQUENTS	D .	AQUULTS	D
ARAPAHOE	B/D	ARCOLA	C	ARGENT	D ·
ASBURN*	С	ASHE	В	ASHLAR	В
ASSATEAGUE	A	ATKINS	D	ATLEE	C
AUGUSTA	C C	AURA	В	AUSTINVILLE	в ч
AXIS	D	AYCOCK	В	BACKBAY	D
BADIN	В	BAILE	D	BAILEGAP	В
BAMA	В	BAYBORO	D	BEACHES	D , .
BECKHAM	В	BELHAVEN	D	BELTSVILLE	C + 1 + 1
BELVOIR	C	BERKS	С	BERMUDIAN	В
BERTIE	В	BIBB	D ,	BILTMORE	A
BIRDSBORO	В	BLADEN	D	BLAIRTON	C
BLAND	C	BLEAKHILL	С	BLUEMONT*	В
BOHICKET	D	BOJAC	В	BOLLING	C 1
BOLTON	В	BONNEAU	A	BOOKWOOD	В
BOTETOURT	C	BOURNE	C ·	BOWMANSVILLE	B/D
BRADDOCK	В	BRADLEY	С	BRANDYWINE	C 1
BRECKNOCK	В	BREMO	С	BRENTSVILLE	C
BROADWAY	В	BROCKROAD	c ·	BRUSHY	В
BUCHANAN	C	BUCKHALL	В	BUCKS	В
BUCKTON	В	BUFFSTAT	В	BUGLEY	C/D
BUNCOMBE	A	BURKETOWN	С	BURROWSVILLE	C
CALVERTON	С	CALVIN	С	CAMOCCA	A/D
CANEYVILLE	C	CARBO	C ,	CARDIFF	В
CAROLINE	C	CARRVALE	D	CARTECAY	С
CATASKA	D .	CATHARPIN	С	CATLETT	C/D
CATOCTIN	C	CATPOINT	A	CAVERNS	В
CECIL	В	CHAGRIN	В	CHAPANOKE	С
		•			

				_	
Soil Name	Hydgrp	Soil Name	Hydgrp	Soil Name	Hydgrp
CHASTAIN	D ,	CHATUGE	D	CHAVIES	В
CHENNEBY	C	CHESTER	В	CHEWACLA	C
CHICKAHOMINY	D	CHILHOWIE	C	CHINCOTEAGUE	D
CHIPLEY	C 1 1 1	CHISWELL	D	CHRISTIAN	C
CID	C	CLAPHAM*	C	CLEARBROOK	D
CLIFTON	C	CLUBCAF	D	CLYMER	D
COASTAL BEACH	D o	CODORUS	С	COLFAX	C
COLLEEN	C	COLVARD	В	COMBS	В
COMUS	В	CONETOE	A	CONGAREE	В ,,
COOSAW	В	COROLLA	D	CORYDON	D 1
COTACO	C	COURSEY	C , , ,	COWEE	В
COXVILLE	D	CRAIGSVILLE	В	CRAVEN	C
CREEDMOOR	C ,	CROTON	D	CULLEN	C
CULPEPER	C	DALEVILLE	$\mathbf{D}_{\mathcal{A}}}}}}}}}}$	DANDRIDGE	D
DAVIDSON	B , , , , , ,	DAWHOO VARIANT	B/D	DECATUR	В
DEKALB	С	DELANCO	C L	DELOSS	B/D
DERROC	В	DILLARD	C	DOGUE	С
DOROVAN	D	DOTHAN	В	DRAGSTON	C
DRALL	В	DRYPOND	D	DUCKSTON	A/D
DUFFIELD	В	DULLES	D	DUMFRIES	В
DUNBAR	D	DUNNING	D	DUPLIN	- C - 1
DURHAM	В	DYKE	В	EBBING	C
EDGEHILL	С	EDNEDYTOWN	В	EDNEYVILLE	В
EDOM	C	ELBERT	D ,	ELIOAK	C
ELIOK	C	ELKTON	C/D	ELLIBER	Α
ELSINBORO	В	EMPORIA	C i	ENDCAV	C
				,	

		_		_	
Soil Name	Hydgrp	Soil Name	Hydgrp	Soil Name	Hydgrp
ENON	С	ENOTT	C	ERNEST	C
EUBANKS	B	EULONIA	C	EUNOLA	С
EVANSHAM	D	EVARD	В	EVERGREEN	В
EXUM	С	FACEVILLE	В	FAIRFAX	В
FALLSINGTON	B/D	FAUGUIER	C	FAYWOOD	C
FEATHERSTONE	D	FISHERMAN	D	FLATWOODS	C
FLETCHER	В	FLUVANNA	C	FLUVAQUENTS	D L
FORESTDALE	D .	FORK	С	FRANKSTOWN	В
FREDERICK	В	FRENCH	C,	FRIPP	A
GAILA	В	GAINESBORO	C	GALESTOWN	A.
GEORGEVILLE	В	GILPIN	C	GLADEHILL	В
GLENELG	В	GLENVILLE	C ;	GLENWOOD	В
GOLDSBORO	В	GOLDSTON	C	GOLDVEIN	C
GORESVILLE*	В	GREENLEE	B	GRIMSLEY	В
GRITNEY	C /	GROSECLOSE	С	GROVER	В
GUERNSEY	C 1	GULLION	C	GUNSTOCK	C
GUYAN	C	GWINNETT VARIENT	В	HAGERSTOWN	С
HALEWOOD	В	HARTLETON	В	HATBORO	D
HAWKSBILL	В	HAYESVILLE	В	HAYMARKET	D
HAYTER	В	HAYWOOD	В	HAZEL	C
HAZEL CHANNERY	C	HAZELTON	В	HELENA	C 1
HERNDON	В	HIWASSEE	В	HOADLY	С
HOBUCKEN	D	HOGELAND*	C	HOLLYWOOD	D
HUNTINGTON	В	HYATTSVILLE	В	HYDE	B/D
HYDRAQUENTS	В	INGLEDOVE	В -	IREDELL	C/D

Soil Name	Hydgrp	Soil Name	Hydgrp	Soil Name	Hydgrp
IRONGATE	В	IUKA	C	IZAGORA	C
JACKLAND	D	JEDBURG	C	JEFFERSON	В
JOHNS	C 77	JOHNSTON	D	JUNALUSKA	В
KALMIA	В	KELLY	D	KEMPSVILLE	В
KENANSVILLE	Α	KENANSVILLE VARIANT	С	KEYPORT	C
KINKORA	D	KINSTON	B/D	KLEJ	В
KLINESVILLE	C/D	KONNAROCK	C	LAIDIG	C
LAKEHURST VARIANT	A	LAKELAND	A	LANEXA	D
LANSDALE	В	LAROQUE	В	LAWNES	D
LEAF	D	LEAKSVILLE	D .	LECK KILL	В
LEEDSVILLE*	В	LEETONIA	C	LEGORE	В
LEHEW	C	LENOIR	D	LEON	B/D
LEVY	$\mathbf{D}_{-\frac{1}{2}} \cdot \mathbf{D}_{-\frac{1}{2}}$	LEW	В	LEWISBERRY	В
LIBRARY	D	LIGNUM	C	LILY	В
LINDSIDE	C	LITTLEJOE	В	LITZ	C
LLOYD	C	LOBDELL	В	LODI	В
LOUISA	В	LOUISBURG	В	LOWELL	C , , , ,
LUCKETTS	В	LUCY	A	LUGNUM	C
LUMBEE	B/D	LUNT	C , ,	LYNCHBURG	C
MACOVE	В	MADISON	В	MAGOTHA	D
MANASSAS	В	MANOR	В	MANTACHIE	С
MANTEO	C/D	MARBIE	C a	MARGO	В
MARLBORO	В	MARR	В	MARUMSCO	C
MASADA	C-	MASSANETTA	В	MASSANUTTEN	В
MATAPEAKE	В	MATNELFLAT	В	MATTAN	D

		_			
Soil Name	Hydgrp	Soil Name	Hydgrp	Soil Name	Hydgrp
MATTAPEX	\mathbf{C}_{i}	MATTAPONI	C	MAURERTOWN	D
MAYODAN	В	MCGARY	C	MCQUEEN	C
MEADOWS	D	MEADOWVILLE	В	MECKLENBURG	C
MEGGETT	D , 1	MELFA	D	MELVIN	D
MILLROCK	A *	MINNIEVILLE	C	MIXED ALLUVIUM	D
MOLENA	A	MONACAN	C	MONGLE	С
MONONGAHELA	С	MONTALTO	C ,	MONTRESSOR*	В
MONTROSS	C	MOOMAW	C	MORRISONVILLE*	В
MORVEN	В	MOUNT LUCAS	C	MT WEATHER*	B 4 7
MUCKALEE	D	MUNDEN	В	MURRILL	В
MYATT	D	MYATT VARIANT	D	MYERSVILLE	В
NAHUNTA	C	NANSEMOND	С	NASON	В
NAWNEY	D	NEABSCO	С	NESTORIA	C/D
NEVARC	C	NEWARK	C	NEWBERN	С
NEWFLAT	D	NEWHAN	A	NEWMARC	C
NICHOLOSON	C	NIMMO	D ,	NIXA	С
NOLICHUCKY	В	NOLIN	В	NOMERVILLE	В
NORFOLK	В	OAKHILL	В	OAKLET	C
OATLANDS	В	OCCOQUAN	В	OCHLOCKONEE	В
OKEETEE	D	OPEQUON	С	ORANGE	D
ORANGEBURG	В	ORENDA	В	ORISKANY	В
OSIER	A/D	OTHELLO	C/D	PACOLET	В
PACTOLUS	Α	PAGEBROOK	D	PAMLICO	D
PAMUNKEY	В	PAMUNKEY VARIANT	A	PANORAMA	В
PARKER	В	PARTLOW	D	PASQUOTANK	B/D
PEAKS	C	PEAWICK	D	PENN	C/D

Soil Name	Hydgrp	Soil Name	Hydgrp	Soil Name	Hydgrp
PHILO	В	PHILOMOMT*	В	PINEYWOODS	D
PINKSTON	В	PISGAH	C .	POCATY	D
POCOMOKE	B/D	POINDEXTER	В	POLAWANA	A/D
POOLER VARIANT	D	POPE	В	POPLIMENTO	C
PORTERS	В	PORTSMOUTH	B/D	POUNCEY	D
PUNGO	D	PURCELLVILLE	В	PURDY	D , ,
RABUM	В	RAINS	B/D	RAMSEY	D .
RAPIDAN	В	RAPPHANNOCK	D	RARITAN	C
RAYNE	В	READINGTON	C	REAVILLE	C 22
REMLIK	A	RIGLEY	В	RION	B .
RIVERVIEW	В	ROANOKE	D	ROHRERSVILLE	D
ROSS	В	ROWLAND	С	RUMFORD	В
RUSHTOWN	Α	RUSTON	В	SAFELL	В
SASSAFRAS	В	SASSAFRAS	В	SAUNOOK	В
SAVANNAH	C	SCATTERSVILLE*	С	SCHAFFENAKER	Α
SEABROOK	C	SEDGEFIELD	С	SEKIL	В
SENECA	В	SEQUOIA	С	SHELOCTA	В
SHENVAL	В	SHERANDO	В	SHEVA	C
SHOTTOWER	В	SINDION	В	SKETERVILLE	C
SLABTOWN	В	SLAGLE	C	SLICKENS	В
SNICKERSVILLE	В	SPEEDWELL	В	SPESSARD	A
SPIVEY	В	SPOSTSYLVANIA	С	SPRIGGS	С
SPRINGWOOD	В	STANTON	D	STARR	C , ,
STATE	В	STEINSBURG	C	STONEVILLE	В
STUART	C	STUMPTOWN	В	SUCHES	В
SUDLEY	В	SUEQUEHANNA	D :	SUFFOLK	В
SUSDLEY	В	SUSQUEHANNA	D , 2 2 2	SWAMP	D

Soil Name	Hydgrp	Soil Name	Hydgrp	Soil Name	Hydgrp
SWEETAPPLE	В	SWIMLEY	С	SYCOLINE	D
SYLCO	C ,	SYLVATUS	D	TALLADEGA	С
TALLAPOOSA	С	TARBORO	A	TATE	В
TATUM	В	TETOTUM	С	THUNDER	В
THURMONT	В	TIDAL MARSH	D	TIMBERVILLE	В
TIOGA	В	TOCCOA	В	TODDSTAV	D
TOMOTLEY	B/D	TOMS	С	TORHUNTA	C
TOTIER	C	TOXAWAY	B/D	TRAPPIST	C
TREGO	В	TRENHOLM	D	TUCKAHOE	В
TUMBLING	В	TURBEVILLE	С	TUSQUITEE	В
TYGART	C	UCHEE	A	UDIFLUVENTS	В
UNISON	В	VANCE	С	VARINA	С
VAUCLUSE	C	VERTREES	В	WADESBORO	В
WAHEE	D	WAKULLA	A -	WALLEN	В
WARMINSTER	C	WATAUGA	В	WATEREE	В
WATT	D	WAXPOOL	D	WEAVER	C
WEAVERTON*	С	WEBBTOWN	С	WEDOWEE	В
WEEKSVILLE	B/D	WEHADKEE	D	WEIKERT	C/D
WESTMORELAND	В	WESTON	D '	WESTPHALIA	В
WEVERTON	В	WHEELING	В	WHITE STONE	D
WHITEFORD	В	WICKHAM	В	WILKES	С
WOLFGAP	В	WOODINGTON	B/D	WORSHAM	D .
WRIGHTSBORO	С	WRYICK	В	WURNO	С
WYRICK	В	YADKIN	C/D	YEMASSEE	С
YEOPIM	В	YORK	С	ZEPP	В
ZION	С	ZOAR	С		

APPENDIX 4C

INFORMATION FROM VDOT HYDRAULIC DESIGN ADVISORIES

Rainfall Intensities (inches/hour) for the Roanoke Valley (Based on VDOT HDA 05-03)

VDOT Hydraulic Design Advisory 05-05; Dan Anderson Peak Discharge Determination – Procedural Revision

RAINFALL INTENSITY (IN/HR) FOR THE ROANOKE VALLEY

							Storm	Dura	tion (1	min)					
		5	10	15	20	25	30	35	40	45	60	75	90	105	120
1	2	4.39	3.51	2.94	2.54	2.24	2.01	1.82	1.67	1.54	1.26	1.07	0.94	0.83	0.75
Interval	5	5.33	4.29	3.62	3.14	2.79	2.52	2.30	2.12	1.96	1.63	1.40	1.23	1.10	1.00
rance I	10	6.04	4.91	4.18	3.66	3.26	2.96	2.71	2.51	2.34	1.96	1.69	1.50	1.35	1.23
Recurrance	25	6.78	5.49	4.68	4.11	3.69	3.36	3.10	2.88	2.70	2.28	2.00	1.79	1.63	1.50
Storm	50	7.37	5.96	5.09	4.49	4.04	3.70	3.42	3.19	3.00	2.56	2.26	2.04	1.87	1.73
	100	8.08	6.49	5.56	4.92	4.46	4.10	3.81	3.57	3.37	2.92	2.61	2.37	2.19	2.04

Table based on VDOT Hydraulic Design Advisory HAD 05-03

$$I_f = B / (t_c + D)^E$$
 where:

 I_f = Rainfall intensity for a given recurrence interval, f, in inches per hour

B,D,E = As taken from HDA 05-03 table for [Roanoke] [Roanoke (city)] based on the designated storm frequency.

 t_c = Watershed time of concentration (assumed to equal the storm duration), in minutes

Hydraulic Design Advisory

1.1 HDA 05-05

2.0 DATE: DECEMBER 15, 2005

3.0 SUBJECT: Dan Anderson Peak Discharge Determinations – Procedural Revision

4.0 AUTHOR: D.M. LeGrande, Sr. (Asst. State Hydraulics Engineer)

As a result of discrepancies discovered in the design charts used with the Dan Anderson procedure (Appendices 6F-1 & 6F-2 from Chapter 6 of the <u>VDOT DRAINAGE MANUAL</u>) and our desire to eliminate, wherever possible and practicable, the use of graphic nomographs, we have revised the procedure for calculating discharges using the Dan Anderson method. The revised procedure eliminates the use of graphic nomographs and utilizes only the equations presented in Anderson's original publication. This will also assist in utilizing the Anderson method with computer programs, spreadsheets, and programmable calculators.

With the issuance of this Hydraulic Design Advisory, Appendices 6F-1 and 6F-2 of the <u>VDOT DRAINAGE</u> MANUAL are voided and the application of the Anderson method for VDOT purposes will be in accordance with the procedure described in the attachment for either manual calculations or computer programs, spreadsheets, or programmable calculators. The procedure described in the attachment will be added to the <u>VDOT DRAINAGE MANUAL</u> Errata Sheet and will be incorporated into the next revision to the <u>VDOT DRAINAGE MANUAL</u>. Areas where changes have been made are highlighted in gray. This revision will affect both Section 6.4.4.2.4 (where the Anderson method is described) and Section 6.5.2.2 (where an example Anderson calculation is shown) of Chapter 6 of the <u>VDOT DRAINAGE MANUAL</u>. If there are any questions, please contact Mr. LeGrande either by phone at (804) 371-2807 or by e-mail at <u>David.LeGrande@VDOT.Virginia.gov</u>.

6.4.4.2.4 Equations

The equation for the Anderson Method is as follows:

$$Q_f = R_f(230)KA^{0.82}T^{-0.48}$$
 (6.6)

Where: $Q_f = Maximum rate of runoff, cubic feet per second (cfs) for flood frequency "f" (i.e.$

2.33, 5, 10, 25, 50, &100). For 500-yr. flood multiply calculated Q₁₀₀ by 1.7.

R_f = Flood frequency ratio for flood frequency "f" based on percentage of imperviousness (obtained from formula shown below)

K = Coefficient of imperviousness (obtained from formula shown below)

A = Drainage area, square miles (sq. mi.)

T = Time lag, hours (See Table 6-3)

Table 6-3. Anderson Time Lag Computation

Time Lag, T	Watershed Description
$4.64 \left(\frac{L}{\sqrt{s}}\right)^{0.42}$	For natural rural watersheds
$0.90 \left(\frac{L}{\sqrt{s}}\right)^{0.50}$	For developed watersheds partially channelized
$0.56 \left(\frac{L}{\sqrt{S}}\right)^{0.52}$	For completely developed and sewered watersheds

Where:

L = Length in miles along primary watercourse from site to watershed boundary

S = Index of basin slope in feet per mile based on slope between points 10 and 85 percent of L

$$K = 1 + 0.015 I$$

Where:

I = Percentage of imperviousness, in whole numbers (e.g. for 20% imperviousness, use I = 20)

$$R_f = \frac{R_N + 0.01I(2.5R_{100} - R_N)}{1.00 + 0.015I}$$

Where:

 R_N = Flood frequency ratio for 0% imperviousness (i.e. completely rural) for flood frequency "f" (see Table 6-3A)

 R_{100} = Flood frequency ratio for 100% imperviousness for flood frequency "f" (see Table 6-3A)

Table 6-3A. Anderson Flood Frequency Ratios

f	2.33	5*	10	25	50	100
R_{n}	1.00	1.65	2.20	3.30	4.40	5.50
R ₁₀₀	1.00	1.24	1.45	1.80	2.00	2.20

^{* -} Flood frequency ratio for the 5-yr. events were derived by VDOT, all others were taken directly from the D.G. Anderson report.

6.5.2.2.1 Anderson Method Sample Problem

Estimate the 25-year peak discharge on Rabbit Branch near Burke, Virginia, for an expected future development consisting of 40% impervious surface and a drainage system of storm sewers for tributaries but a natural main channel.

Step 1: From topographic maps, determine the following data

$$A = 3.81$$
 sq. miles

L = 3.40 miles from crossing site to watershed boundary Elevation = 282 feet at 10%L (0.34 miles) above crossing site 395 feet at 85%L (2.90 miles) above crossing site

Step 2: Compute the average channel slope

Slope =
$$\frac{(395-282)}{(2.90-0.34)} = \frac{113}{2.56} = 44.2 \text{ ft/mi}$$

Step 3: Compute time - T

$$T = 0.9 \left(\frac{L}{\sqrt{S}}\right)^{0.5}$$
 for Developed Watershed, Partly Channeled

Step 4: Compute K

$$K = 1.00+0.015 \text{ I}$$
, where $I = 40\%$ for impervious surface = $1.00+0.015(40)$ = 1.60

Step 5: Compute Flood Ratio (Rf) using equation from section 6.4.4.2.4 with a 25-yr RN of 3.3 and a 100-yr R100 of 1.8

$$R_{25} = [R_{N} + 0.01I(2.5R_{100} - R_{N})] / K$$

= [3.3 + 0.01(40)(2.5(1.8) - 3.3)]/1.6
= 2.36

Step 6: Compute peak discharge (Q)

$$Q_{25} = R(230)KA T^{0.82} -0.48$$

$$= 2.36(230)(1.6)(3.81) (0.64)^{-0.48}$$

$$= 3222 \text{ cfs (Say 3200 cfs)}$$

Chapter 5 – Open Channels

Open channels are man-made ditches and channels and natural channels, that are used to convey stormwater flow. This section defines criteria and restrictions to be used in designing open channels.

Grassed swales are a type of water quality BMP, and are not considered as an open channel. Use and design requirements for grassed swales are contained in Chapter 11.

5.1 References

Except where more stringent requirements are presented in this Design Manual, open channels shall comply with VDOT and DCR requirements. The primary design references are:

- VDOT Drainage Manual
- VDOT Specifications
- VA E&SC Handbook
- Hydraulic Engineering Circular Number 15 (HEC-15), Design of Roadside Channels with Flexible Linings, Current Edition, as amended

5.2 Design Methodology and Criteria

5.2.1 Major and Minor Channels

Open channels are classified as either major channels or minor channels.

A major channel is designed to convey less frequent storm events which would have significant adverse consequences if it failed. Major channels protect buildings and other important features from flooding and catastrophic failures. They may include emergency spillways, man-made channels, and natural watercourses.

A minor channel is designed to convey more frequent storm events and they include most open channels and roadside ditches. These structures have less adverse consequences due to overtopping.

5.2.2 Design Flow

Design flow for open channels is contained in Chapter 4. Design flows for open channels must be contained within the channel with adequate freeboard from the top of the bank to the peak water level.

5.2.3 Hydrology

See Chapter 4 for methodology used to determine peak flows for a given design frequency.

5.2.4 Channel Hydraulics

Open channel design will be based on Manning's Equation for open channel flow:

$$Q = A \times 1.49/n \times R^{2/3} \times S^{1/2}$$

Where:

Q = Flow in the open channel (cfs)

A = Cross-section area of the channel (ft²)

R = A/wetted perimeter (ft)

S = Channel slope (ft/ft)

n = Channel roughness coefficient

Nomographs have been included in Appendix 5A for use in solving Manning's equation setting channel characteristics.

5.2.5 Channel Velocity

The lining of minor channels with drainage areas of five acres and less shall be designed to withstand the erosive effects of a 2-year storm. The lining of minor channels with drainage areas over five acres and major channels shall be designed to withstand the erosive effects of a 10-year storm. The final design shall be consistent with velocity limitations for the selected channel lining, as presented in Table 5-1.

Major channels associated with dam embankment spillways or other structures where catastrophic failure could result from a lining failure may be required to be designed to withstand a more severe storm event.

Where open channels receive flow from storm drains, culverts, or other open channels, or in other areas where channel velocity may cause scouring or erosion, outlet protection or energy dissipation may be necessary to reduce the potential for severe erosion. For the design of energy dissipation devices, see Chapter 10.

TABLE 5-1
Maximum Velocity Based on Channel Lining

Channel Lining	Maximum Velocity			
	(Design)	Storm)		
	Erosion Resistant	Easily Erodible		
	Soils ¹	Soils ²		
Vegetative Lined Channels				
Tall Fescue Grass Mixtures	6 fps	4 fps		
Kentucky Bluegrass	6 fps	4 fps		
Annual and Perennial Rye	4 fps	3 fps		
Sod	4 fps	3 fps		
Geosynthetic Lined Channels				
VDOT EC-2	4 fp	OS		
VDOT EC-3, Type A	7 fp	OS		
VDOT EC-3, Type B	10 f	ps		
Other	Per Mfr			
	Recomme	ndations		
Riprap	Dependent on s	stone size and		
	thickness, see HEC	2-15 for design of		
	riprap ch	annels		
Concrete	Nor	ne		

¹ Erosion resistant soils include those with a high clay content and high plasticity, silty clay, sandy clay, and clay.

5.2.6 Channel Slope

Generally the channel slope shall be established by the site topography. Open channels must be graded to drain with no standing water following a rain event. The minimum allowable grade shall be 2 percent for vegetated-lined and riprap-lined open channels and 1 percent for a concrete open channel.

The maximum allowable grade for a stormwater channel shall be dependent on the channel lining materials and its ability to withstand erosion during the design storm.

² Easily erodible soils include those with a high content of fine sand or silty, lower plasticity or non-plastic, sand, silt, sandy loam, and silty loam with an erodibility factor (K) greater than 0.35.

5.2.7 Cross Sectional Area

Open channel cross-section area shall be designed based on site restrictions and channel capacity requirements.

Acceptable cross-sectional area options include:

- Vee
- Parabolic
- Trapezoidal
- Rectangular

A. Vee

For design aids, see the VDOT Drainage Manual and the VA E&SC Handbook.

The maximum side slope of a vee-shape open channel is 3 horizontal to 1 vertical for natural or vegetated channels and is 2 horizontal to 1 vertical for all other linings engineered to be stable at this slope.

B. Parabolic

For design aids, see the VDOT Drainage Manual and the VA E&SC Handbook.

C. Trapezoidal

For design aids, see the VDOT Drainage Manual and the VA E&SC Handbook.

The maximum side slope of a trapezoidal-shape open channel is 3 horizontal to 1 vertical for natural or vegetated channels and is 2 horizontal to 1 vertical for all other linings engineered to be stable at this slope.

D. Rectangular

Rectangular channels shall only be allowed where site restrictions prevent the installation of a vee, parabolic, or trapezoidal channel.

The requirements for rectangular channels apply to any open channel with side slopes greater than 2 horizontal to 1 vertical.

Rectangular channels must either be concrete or gabions.

An approved safety barrier must be placed on both sides for the length of the rectangular channel, where the channel is more than 3-feet deep.

Care must be taken to ensure that energy dissipation is placed at the outfall of the rectangular channel to prevent erosion at the discharge point.

5.2.8 Channel Lining

An open channel lining shall be designed based on the cross-section, slope, and channel velocity requirements. The design may be based on a consideration of either permissive velocity or tractive force as described in the VDOT Drainage Manual.

The preferred method for analyzing channel linings is to compare the maximum permissible velocity for the channel lining, listed in Table 5.1 in this chapter of the Design Manual, to the design velocity computed using Manning's equation to verify the selected lining is adequate. As an alternative, the selected lining may be analyzed using the Tractive Force Method published in the VDOT Drainage Manual. This method analyzes sediment critical shear loading on the open channel bottom and side slope. The permissible tractive force for various soils is located in the Appendix of the VDOT Drainage Manual.

Open channels may have different lining materials in different channel reaches based on velocity and potential erosion conditions. Care must be exercised to avoid erosion at open channel transition points.

The open channel lining will have an impact on the design capacity in the form of the roughness coefficient. A table of generally accepted roughness coefficient (n) for various channels and linings is included in Appendix 5A.

Allowable open channel linings include the following:

A. Natural

To the extent possible, natural channels shall be preserved.

To determine the permissive velocities in natural channels, based on soil conditions, use permissible velocities based on soil conditions published in the VA E&SC Handbook. If the design storm velocity exceeds the permissible velocity, a natural channel cannot convey the stormwater runoff without modifying the discharge flow conditions or the natural channel.

B. Vegetative-Lined

Vegetated or grass-lined channels include man made channels lined with established vegetation. These channels usually include a geosynthetic mat for channel stabilization.

The type of grass allowable for vegetative-lined open channels is dependant on the slope of the channel, and the peak calculated velocity. Table 5-1 details the maximum permissible velocities for various channel linings.

A permanent channel stabilization geosynthetic mat should be considered for all vegetated channels. There are a wide variety of geosynthetic stabilization mat options from various manufacturers. The geosynthetic mat selected should be adequate for the slope and design flow velocities calculated for the channel. Where appropriate, VDOT Road and Bridge Standard EC-2 or EC-3 may be used.

Where a permanent geosynthetic mat is used to provide channel stabilization, information on the proposed mat, in the form of manufacturer's catalog information, shall be submitted as a part of the stormwater management plan. The catalog information shall include the manufacturer's recommendations for maximum allowable velocity. Design drawings must state that the geosynthetic stabilization mat shall be installed in strict accordance with the manufacturer's recommendations.

Where a permanent channel stabilization geosynthetic is not used, a temporary geosynthetic lining designed to provide a measure of bank stability until such time a reasonably stable and mature stand of vegetation is established shall be provided.

C. Riprap-Lined

The use of vegetated and geosynthetic-lined open channels for gentle-sloped open channels and concrete for steep-sloped open channels is encouraged. Riprap-lined channels will not be acceptable where vegetated or geosynthetic-lined open channels are feasible. However, where design flow velocities exceed the erosive capability of a natural or vegetative-lined channel, rip rap may be used as a channel liner in areas where erosion is a concern. For an extended length of high velocity channel, consideration should be given to using a concrete channel rather than rip rap.

Use of riprap-lined channels requires pre-approval from the County of Roanoke.

Where riprap is approved by the County of Roanoke, it shall meet VDOT Standards and VDOT Specifications. VDOT recommended 50 percent stone size (D_{50}) and weight (W_{50}) and recommended thickness (T) for various riprap classifications is included in Appendix 5A.

D. Concrete-Lined

Concrete shall be considered where design velocities dictate or where there is a need to provide the maximum level of erosion protection.

5.2.9 Freeboard Requirements

Minor channels shall have a minimum of 6" of freeboard above the calculated water level during the design peak flow, unless flow is supercritical. Where flow is supercritical, a minimum of 12" of freeboard is required. Flow is supercritical when:

$$V / (32.2 \text{ x H})^{0.5} > 1$$

 $V = \text{velocity (fps)}$
 $H = \text{depth of flow (feet)}$

Major channels shall have a minimum of 12" of freeboard above the calculated water level during the design peak flow.

At bends and curves, the freeboard shall be measured from the calculated water level, including the increased depth due to the superelevation of the water surface.

5.2.10 Calculation of Depth of Flow at Bends and Curves

Increases in the depth of flow occur at bends and curves due to the superelevation of the water surface. Superelevation of the water surface at bends and curves is calculated by:

$$\Delta Z = V^2 / (32.2 \text{ x r}_c) \text{ x (r}_o - r_i) \text{ where}$$

 ΔZ = difference in water surface elevation between the concave and convex banks (ft)

V = average velocity (ft/s)

 r_c = radius of the center of the stream at the bend (ft)

 r_0 = radius of the outside bank of the stream at the bend (ft)

 r_i = radius of the inside bank of the stream at the bend (ft)

The increase in the normal stream flow depth at the outer bank of an open channel bend is one half of ΔZ .

5.2.11 Channel Location and Width Restrictions on Residential Lots

In no event shall the tops of open channel banks be located any closer than 20-feet to a residence.

Where open channels collect stormwater from more than one lot and they are located on a residential zoned lot their use shall be restricted as follows. Where all requirements cannot be met, a closed pipe storm drain system is required.

- Residential lot size 1 acre or greater
 - No additional restrictions.

- Residential lot size 0.5 acre or greater, but less than 1 acre
 - Open channel top width shall be a maximum of 15 feet
 - Maximum drainage area passing through the open channel shall be 5 acres.
- Residential lot size less than 0.5 acre
 - Open channel top width shall be a maximum of 15 feet
 - Maximum drainage area passing through the open channel shall be 3 acres.

The above restrictions do not apply if any one of the following conditions is present:

- The open channel is a natural channel that has adequate capacity and will remain undisturbed. The retention of natural channels is encouraged.
- The open channel is a perennial or intermittent stream that has adequate capacity and will remain undisturbed.
- It may be demonstrated that open channels are required as a part of an integrated design to obtain the necessary water quality treatment.

5.3 Adequate Channels

Minimum Standard 19 (MS 19) from the VA E&SC Handbook establishes that concentrated stormwater runoff leaving a development site must be discharged directly into an adequate natural or man-made receiving channel, pipe, or storm sewer system. If there is no well-defined off-site receiving channel or pipe, one must be constructed to convey stormwater to the nearest adequate channel. In addition all newly constructed channels shall be designed as adequate channels.

An adequate channel is defined as:

- A natural channel, which is capable of conveying the runoff from a 2 year storm without overtopping its banks nor eroding the channel bed or banks.
- A previously constructed man-made channel which is capable of conveying the runoff from a 10-year storm without overtopping its banks, and conveying the runoff from a two-year storm without causing the erosion of channel bed or banks.
- Pipes and storm sewer systems which can contain a 10-year frequency storm.

If existing natural receiving channels or previously constructed man-made channels or piped systems are not adequate, the applicant shall:

• Improve the channels to a condition where a 10-year frequency storm will not overtop the banks and a two-year frequency storm will not cause erosion of the channel bed or banks.

- Improve the pipe or pipe system to where a 10-year frequency storm can be contained within the pipe and appurtenances.
- Where no downstream channel exists, the applicant shall provide a site specific combination of channel establishment or improvement, stormwater detention/retention or other measures which is satisfactory to the County of Roanoke to prevent downstream erosion.

5.4 Environmental Considerations and Fishery Protection

Construction or modifications to open channels shall comply with all applicable laws and regulations. The applicant is responsible for procuring all necessary permits, such as US Army Corps of Engineers and VA DEQ Wetland Permits, VA DCR VSMP Permits, VA DEQ VPDES Permits, etc., prior to obtaining a Land Disturbance Permit.

5.5 Maintenance Requirements

The permittee is responsible for maintenance of open channels until construction is complete, including final clean up and site stabilization, to the satisfaction of the County of Roanoke. After the completion of construction, the property owner is responsible for maintenance of open channels. Maintenance includes periodically pruning or mowing vegetation and removing debris.

No one shall fill, modify, or construct structural modifications which impairs or restricts flow in open channels. Property owners shall periodically prune vegetation to avoid restricting flow capacity and shall correct erosion damage as necessary.

5.6 Floodplain Studies

A floodplain study shall be performed for all drainage areas greater than 100 acres that do not have detailed FEMA Flood Insurance Study flood profiles or elevations. See Chapter 12 for additional information on floodplain requirements.

APPENDIX 5A

AIDS FOR OPEN CHANNEL DESIGN

FROM CHAPTER 7, VDOT DRAINAGE MANUAL

Appendix 7B-1, LD-268, Roadside and Median Ditch Design Form

Appendix 7B-3, Channel Stability Work Sheet

Appendix 7B-4, Riprap Design Work Sheet for Standard VDOT Riprap Sizes Only

Appendix 7B-5, Riprap Design Work Sheet for other than VDOT Standard Riprap Sizes

Appendix 7C-1, Nomograph for Solution of Manning's Equation

Appendix 7C-2, Trapezoidal Channel Capacity Chart

Appendix 7C-3, Nomograph for Solution of Normal Depth

Appendix 7D-1, Values of Roughness Coefficient n, 2 sheets

Appendix 7D-3, Standard VDOT Riprap Classifications, Weights, and Blanket Thickness

Appendix 7D-5, Selection of Stability Factors

Appendix 7D-6, Permissible Velocities for Erodible Linings

Appendix 7E-1, Angle of Repose of Riprap in Terms of Mean Size and Shape of Stone

Appendix 7E-2, Permissible Shear Stress for Non-Cohesive Soils

Appendix 7E-3, Permissible Shear Stress for Cohesive Soils

Appendix 7E-4, Bank Angle Correction Factor (K₁) Nomograph

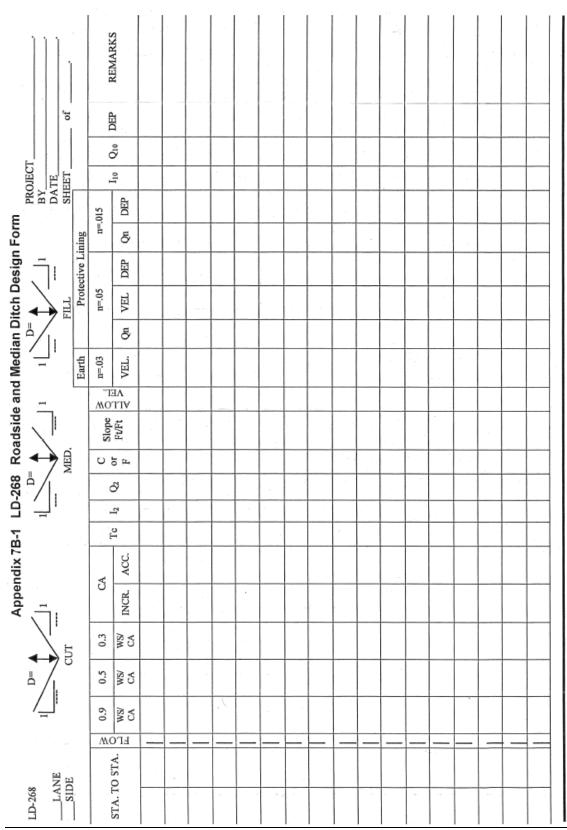
Appendix 7E-5, Correction Factor for Riprap Size

Appendix 7E-6, Riprap Size Relationship

Appendix 7E-7, Channel Side Shear Stress to Bottom Shear Stress Ratio

Appendix 7E-8, Tractive Force Ratio (K₂)

Appendix 7E-9, Determination of Mean Spherical Diameter



CHANNEL STABILITY WORKSHEET

CHANNEL DATA

$$P = (ft.)$$

$$S_0 =$$
_____(ft/ft) $R =$ _____(ft.) $D_{50} =$ _____

$$R = (ft.)$$

$$d_n =$$
 (ft.)

$$d_n =$$
____(ft.) $V_n =$ ____(fps) $D_{75} =$ ____

$$A = \underline{\hspace{1cm}} (ft^2)$$

$$A = (ft^2)$$
 Side Slope = :1 n =

STABILITY OF NATIVE MATERIAL

 τ_0 = 62.4 • R • S₀ = 62.4 • _____ • ___ = ____

 τ_p Bed = (Appendix 7E-2 or 3)

For $D_{50} = ____ \phi = ____^{\circ}$ (Appendix 7E-1)

For $D_{75} = ____ \phi = ____^{\circ}$ (Appendix 7E-9)

Side Slope = $\underline{}$:1 θ = $\underline{}$

 $K_1 = [1 - (\sin^2 \theta / \sin^2 \phi)]^{0.5}$

 $K_1 = [1 - (\sin^2 \underline{}^{\circ} / \sin^2 \underline{}^{\circ})]^{0.5} = \underline{}^{\circ}$

 τ_s Side Slope (SS) = τ_p Bed • K = ___ =

 $\tau_{\rm o}$ Bed (______) (<) (=) (>) $\tau_{\rm o}$ (______)

... Native Material on Bed is (stable) (unstable)

 τ_{s} SS (______) (<) (=) (>) τ_{o} (_____)

... Native Material on Side Slope is (stable) (unstable)

RIPRAP DESIGN WORKSHEET (VDOT STANDARD SIZES)

CHANNEL DATA

$$S_o = \underline{\hspace{1cm}} (ft/ft)$$

$$R =$$
 (ft.)

$$d_n = (ft.)$$

$$A = ____(ft.^2)$$

DETERMINE RIPRAP SIZE

$$\phi = 42^{\circ}$$
 Side Slope = _____ : 1 $\theta =$ _____ °

$$K_1 = [1 - (\sin^2 \theta / \sin^2 \phi)]^{0.5}$$

$$K_1 = [1 - (\sin^2 _ 0 / \sin^2 42^\circ)]^{0.5} = _ 0$$

For Specific Gravity = 2.65 and Stability Factor = 1.2

$$D_{50} = 0.001 \cdot V_a^3 / (d_{avg}^{0.5} \cdot K_1^{1.5})$$

Note: All VDOT standard riprap (Class AI through Type II) is assumed to have a ϕ of approximately 42° and a Specific Gravity of 2.65. Therefore, the Computed D₅₀ should be adjusted by the Stability Correction Factor (C_{SF}) (if any) to derive a Final D₅₀. The VDOT standard class of riprap with the next higher D₅₀ should be specified.

Correction Factor For Stability Factor (SF) other than 1.2 (Default = 1.0)

$$C_{SF} = (SF / 1.2)^{1.5} = (____ / 1.2)^{1.5} = ____$$

RIPRAP DESIGN WORKSHEET (NON-VDOT STANDARD SIZES)

011				- 4
CH	ANI	۱H	DA [*]	IΑ

$$P = (ft.)$$

$$S_o = ____(ft/ft)$$

$$d_n = ____(ft.)$$

$$V_n = \underline{\hspace{1cm}} (fps)$$

$$A = ____(ft^2)$$

ASSUMED RIPRAP SIZE - D₅₀ =

VERIFY ASSUMED RIPRAP SIZE

$$\phi = _{\circ} (Appendix 7E-1)$$

Side Slope = ____: 1 $\theta = _{\circ} K_1 = [1 - (\sin^2 \theta / \sin^2 \phi)]^{0.5}$

$$K_1 = [1 - (\sin^2 \theta / \sin^2 \phi)]^{0.5}$$

$$K_1 = [1 - (\sin^2 - \cos^2 + \sin^2 - \cos^2)]^{0.5} =$$

For Specific Gravity = 2.65 and Stability Factor = 1.2

$$D_{50} = 0.001 \cdot V_a^3 / (d_{avg}^{0.5} \cdot K_1^{1.5})$$

Assumed D₅₀ is (correct) (incorrect)

Note: The above process of assuming a D₅₀ size, determining the natural angle of repose (φ) and computing a D₅₀ size should be repeated until the Assumed D₅₀ size equals the Computed D₅₀ size. Once the D₅₀ size determination has been made, it should be adjusted for the Specific Gravity Correction Factor C_{sq} (if any) and the Stability Correction Factor (C_{SF}) (if any) to derive a Final D₅₀.

Correction Factor For Riprap Specific Gravity (S_s) other than 2.65 (Default = 1.0)

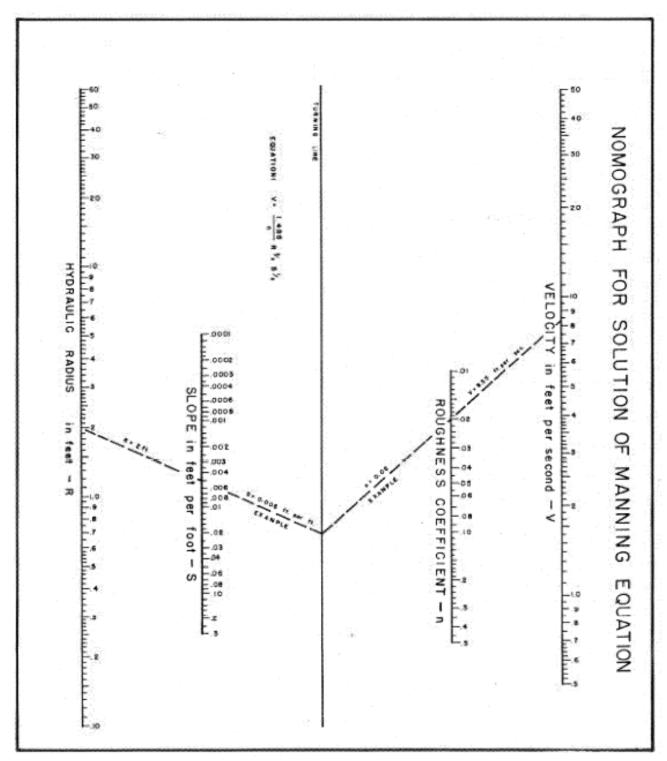
$$C_{sg} = 2.12 / (S_s - 1)^{1.5} = 2.12 / (____ - 1)^{1.5} = ____$$

Correction Factor For Stability Factor (SF) other than 1.2 (Default = 1.0)

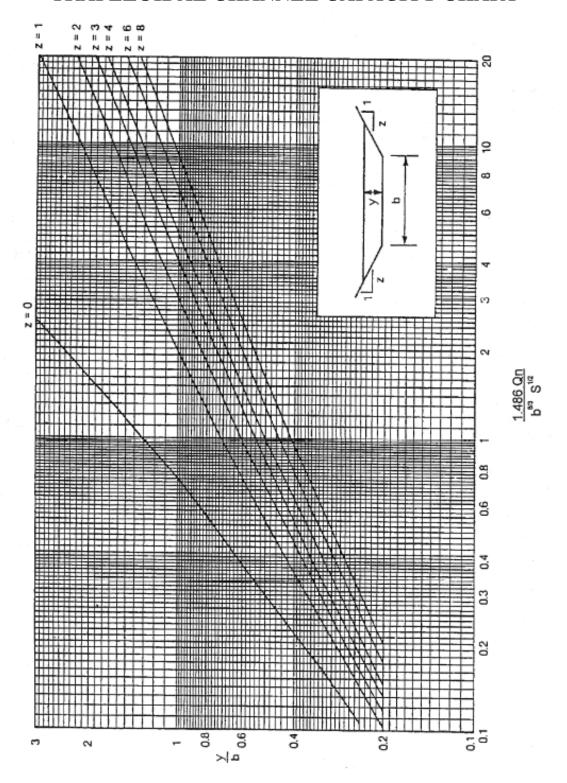
$$C_{SF} = (SF / 1.2)^{1.5} = (____ / 1.2)^{1.5} = ____$$

RIPRAP RECOMMENDATION: _____

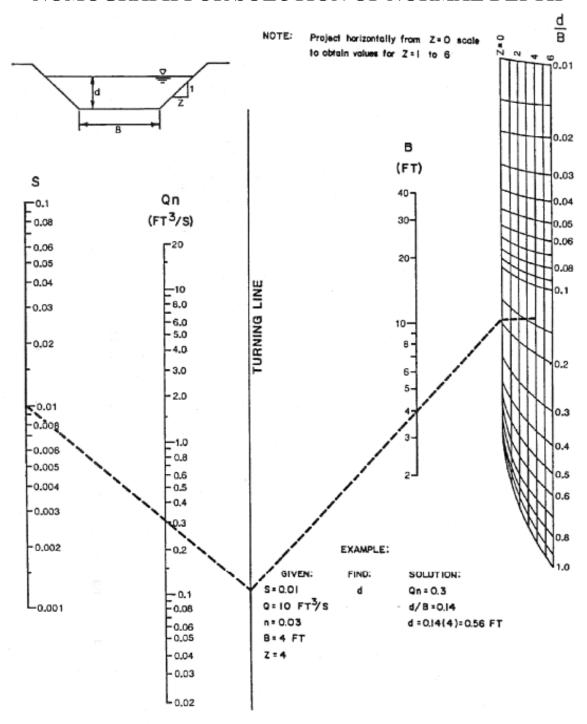
NOMOGRAPH FOR SOLUTION OF MANNINGS EQUATION



TRAPEZOIDAL CHANNEL CAPACITY CHART



NOMOGRAPH FOR SOLUTION OF NORMAL DEPTH



VALUES OF ROUGHNESS COEFFICIENT 'n' CHANNELS

Type of Channel and Description	Minimum	Normal	Maximum
LINED CHANNELS (Selected linings)			
a. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Gunite, good section	0.016	0.019	0.023
b. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.035
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.025	0.030	0.035
Stony bottom and weedy sides	0.025	0.035	0.045
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140

VALUES OF ROUGHNESS COEFFICIENT 'n' NATURAL STREAMS

Type of Channel and Description	Minimum	Normal	Maximum
NATURAL STREAMS	TVIIIIIIIIIIIII	110111141	Mannum
1. Minor streams (top width at flood stage <100 ft)			
a. Streams on Plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
	0.023	0.030	0.033
2. Same as above, more stones and weeds			
3. Clean, winding, some pools/shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective	0.040	0.048	0.055
slopes and sections	0.045	0.050	0.060
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very reedy reaches, deep pools or floodways	0.075	0.100	0.150
with heavy stand of timber and underbrush			
b. Mountain Streams (no vegetation in channel,			
banks usually steep, trees and brush along banks			
submerged at high stages)			
1. Bottom: gravels, cobbles, few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
2. Floodplains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated area			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees	0.070	0.100	0.100
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.130	0.250
3. Same as above, but with heavy sprout growth	0.050	0.040	0.030
4. Heavy stand of timber, a few down trees, little	0.030	0.000	0.080
undergrowth, flood stage below branches	0.000	0.100	0.120
5. Same as above, but with flood stage reaching	0.100	0.120	0.160
branches	0.100	0.120	0.100
3. Major Streams (top width at flood stage >100 ft)	0.025		0.060
a. Regular section with no boulders or brush	0.025		0.060
b. Irregular and rough section	0.035		0.100
(The n value is less than that for minor streams of the			
same description, because banks offer less effective			
resistance.)			

STANDARD VDOT RIPRAP CLASSIFICATIONS, WEIGHTS, AND BLANKET THICKNESS

Classification	D ₅₀ (ft)	W ₅₀ (lbs)	T (in)
Class AI	0.8	50	20
Class I	1.1	100	26
Class II	1.6	300	38
Class III	2.2	1000	53
Type I	2.8	2000	60
Type II	4.5	8000	97

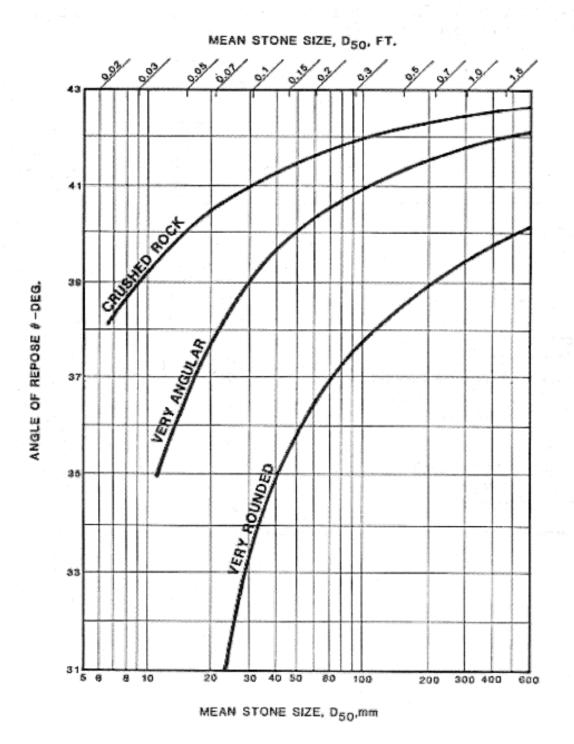
SELECTION OF STABILITY FACTORS

Condition	Stability Factor Range
Uniform flow; straight or mildly curving reach (curve radius/channel width >30); impact from wave action and floating debris is minimal; little or no uncertainty in design parameters.	1.0 - 1.2
Gradually varying flow; moderate bend curvature (30 > curve radius/channel width > 10); impact from waves or floating debris is moderate.	1.3 - 1.6
Approaching rapidly varying flow; sharp bend curvature (30 > curve radius/channel > 10); significant impact from floating debris and/or ice, significant wind and/or bore generated waves (1-2 feet); high flow turbulence; mixing flow at bridge abutments; significant amount of uncertainty in design parameters.	1.6 - 2.0
Channel bends when ratio of curve radius to channel width $(R/W) > 30$.	1.2
Channel bends when $30 > R/W > 10$.	1.3 - 1.6
Channel bends when R/W < 10.	1.7

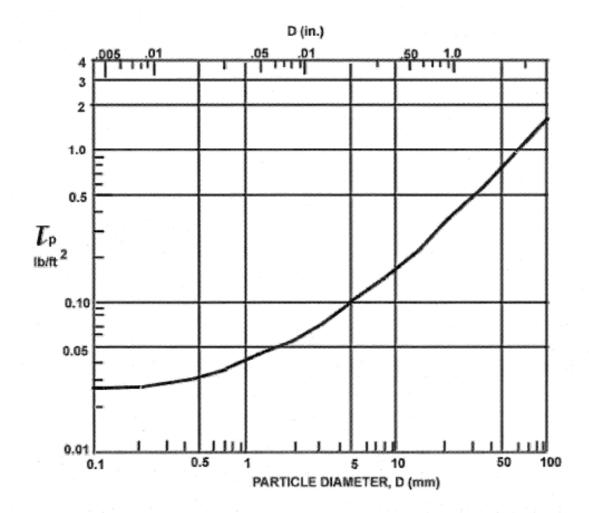
PERMISSIBLE VELOCITIES FOR ERODIBLE LININGS

	Maximu	n permissible velocities (ft/sec) for		
Soil type or lining (earth; no vegetation	Clear water	Water carrying fine silts	Water carrying sand and gravel	
Fine sand (non colloidal)	1.5	2.5	1.5	
Sandy loam (non colloidal)	1.7	2.5	2.0	
Silt loam (non colloidal)	2.0	3.0	2.0	
Ordinary firm loam	2.5	3.5	2.2	
Volcanic ash	2.5	3.5	2.7	
Fine gravel	2.5	5.0	3.7	
Stiff clay (very colloidal)	3.7	5.0	3.0	
Graded, loam to cobbles (non colloidal)	3.7	5.0	5.0	
Graded, silt to cobbles (colloidal)	4.0	5.5	5.0	
Alluvial silts (non colloidal)	2.0	3.5	2.0	
Alluvial silts (colloidal)	3.7	5.0	3.0	
Coarse gravel (non colloidal)	4.0	6.0	6.5	
Cobbles and shingles	5.0	5.5	6.5	
Shales and hard pans	6.0	6.0	5.0	

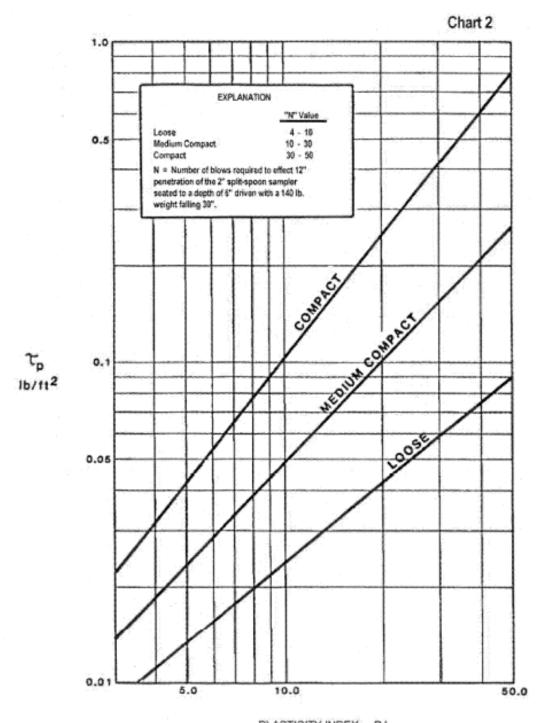
ANGLE OF REPOSE OF RIPRAP IN TERMS OF MEAN SIZE AND SHAPE OF STONE



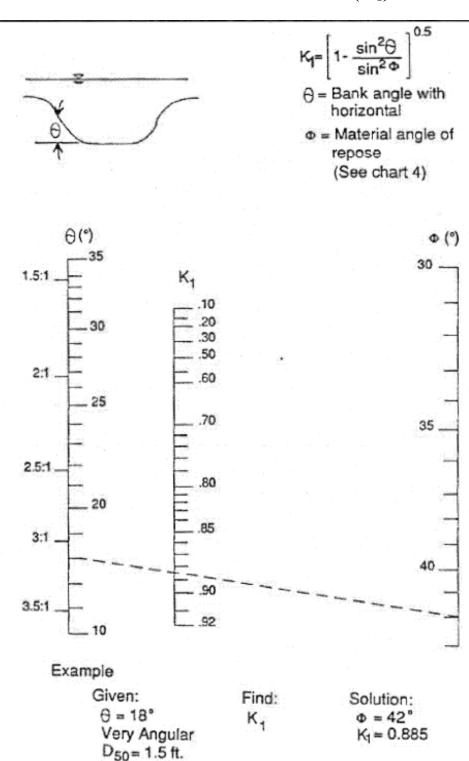
PERMISSIBLE SHEAR STRESS FOR NON-COHESIVE SOILS



PERMISSIBLE SHEAR STRESS FOR COHESIVE SOILS



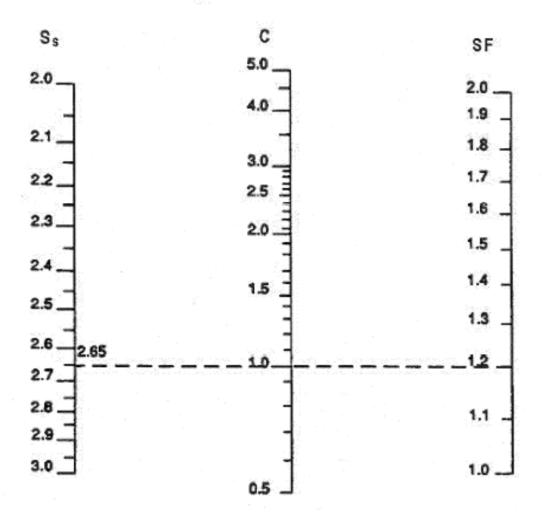
BANK ANGLE CORRECTION FACTOR (K₁) NOMOGRAPH



CORRECTION FACTOR FOR RIPRAP SIZE

C = 1.61 SF1.5/(Ss -1)1.5

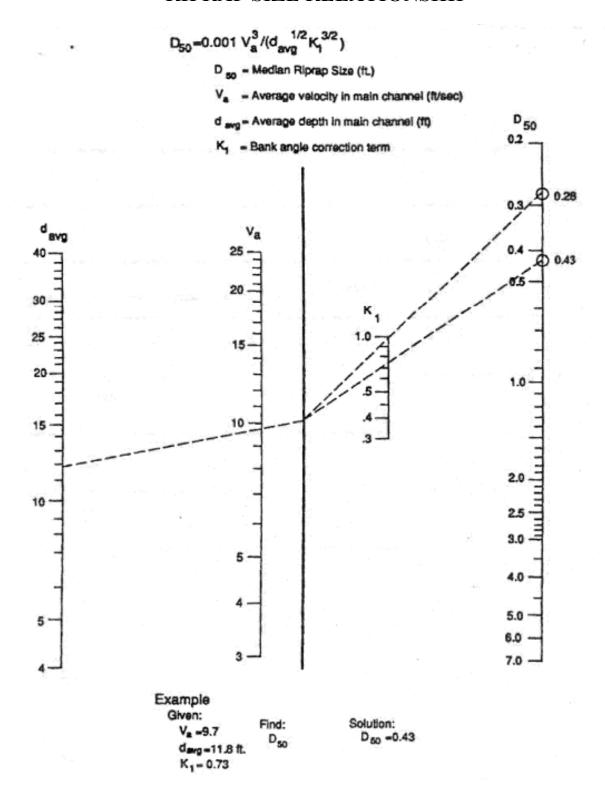
C = D 50 CORRECTION FACTOR SF = STABILITY FACTOR Ss = SPECIFIC GRAVITY OF ROCK



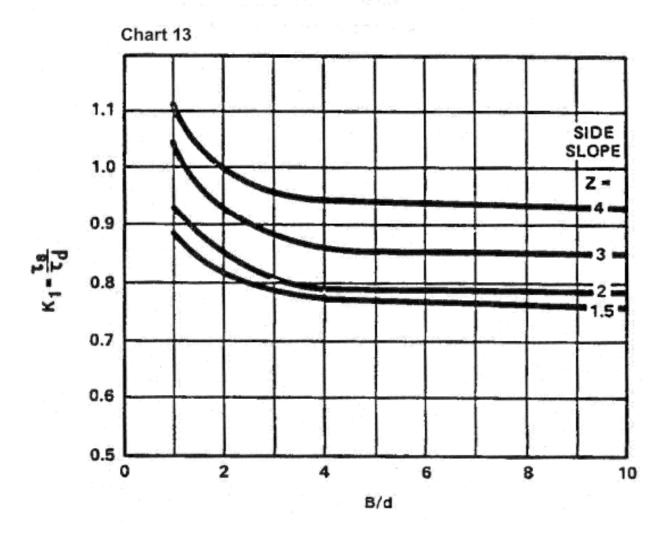
Example:

Given: S_S = 2.65 SF = 1.2 Solution: C = 1.0

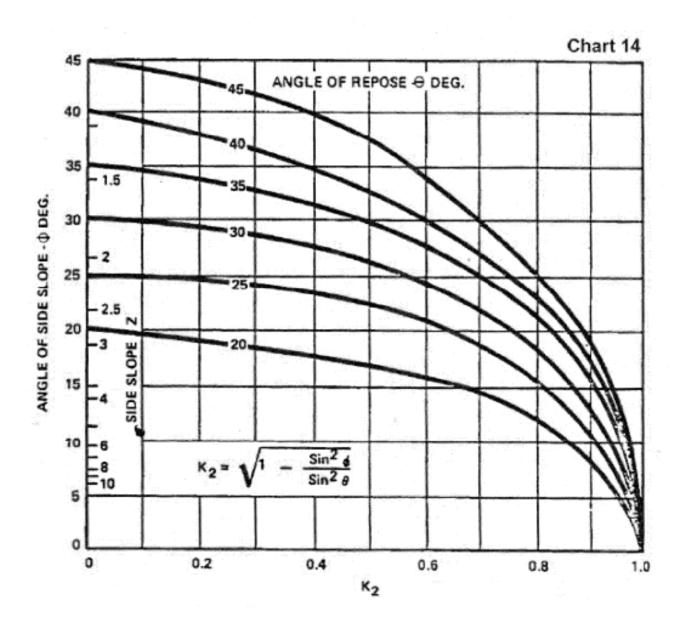
RIPRAP SIZE RELATIONSHIP



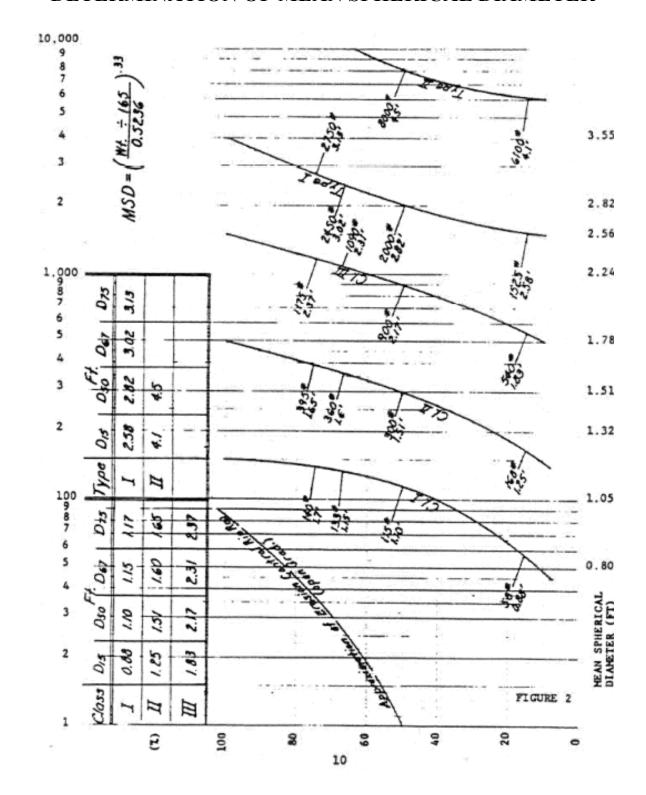
CHANNEL SIDE SHEAR STRESS TO BOTTOM SHEAR STRESS RATIO



TRACTIVE FORCE RATIO (K₂)



DETERMINATION OF MEAN SPHERICAL DIAMETER



Chapter 6 - Culverts

A culvert is a single run of storm drain pipe that conveys water or stormwater under a road, railway, embankment, sidewalk, or other obstruction. A culvert typically connects two open channels, but they may connect an open channel to a storm drain.

Proper culvert design must consider many factors including:

- Design Flow
- Inlet conditions (flow approach conditions, allowable headwater, culvert inlet configuration)
- Culvert conditions (material roughness, pipe slope, and length)
- Tailwater depth
- Buoyancy potential
- Environmental considerations and effects on aquatic life
- Design loads and service life of the pipe material

Refer to the VDOT Drainage Manual, for a more through discussion of these items.

For the design of stormwater inlets and storm drains, see Chapter 7.

6.1 References

Except where more stringent requirements are presented in this Design Manual, culverts shall comply with VDOT requirements. The primary design reference is the VDOT Drainage Manual. Other appropriate references include:

- VDOT Standards
- VDOT Specifications
- VA E&SC Handbook
- VDOT Instructional and Informational Memorandum IIM-ID-121.15, Allowable Pipe Criteria for Culverts and Storm Sewers
- FHWA Hydraulic Design of Highway Culverts HDS No. 5, Pub. No. FHWA-NHI-01-020, Current Edition, as amended
- FHWA Debris Control Structures Evaluation and Countermeasures HEC No. 9, Pub. No. FHWA-IF-04-016, Current Edition, as amended

9/11/07 6-1 CULVERTS

6.2 Design Methodology and Criteria

6.2.1 Computation Methods

Computations may be manual or by computer program.

Manual computations use design equations and nomographs. Results are documented on VDOT's Design Form LD-269. Form LD-269 is included in Appendix 6A.

There are a number of computer programs available to design culverts. Any of these computer programs will be acceptable if their methodologies are based on the same equations and nomographs accepted by VDOT, and if they provide the same documentation of inputs, assumptions, and output as are contained on VDOT's Design Form LD-269.

6.2.2 Hydrology

A. Design Flow Methodology

See Chapter 4 for methodology used to determine design flows. Generally culverts shall be designed based on the peak flow (steady state), ignoring the effects of temporary upstream storage.

B. Obstruction Allowance

Roanoke County reserves the right to require an obstruction allowance in critical areas where excessive backwater may result in property damage or a potential safety hazard.

After using the appropriate design methodology to calculate the peak stormwater flow for a given frequency, an obstruction allowance will be added to the peak flow to establish the design flow rate through the culvert. The obstruction allowance factor is intended to account for normal culvert obstructions, which may lower the actual capacity of the culvert once constructed, and is based on the size of the culvert pipe in accordance with the following tabulation:

<u>Culvert Size</u>	Obstruction Allowance Factor
18" and less	25%
21"-24"	20%
30"	15%
36" and greater	10%

6.2.3 Culvert Hydraulics

A. Design Flow

The design flow shall be the peak flow from the following frequency storm event, plus the appropriate obstruction allowance:

Roadway Storm Frequency

Primary & Arterial 25-year Secondary & Other 10-year

These frequencies are minimum values. Designing for less frequent storms may be required where there is potential damage to structures, loss of human life, injury, or heavy financial loss in the event of flooding.

Compliance with the National Flood Insurance Program (NFIP) is necessary for all locations where construction will encroach on a 100-year frequency flood plain.

In addition, the 100-year peak flow (without the addition of the obstruction allowance) shall be routed through all culverts, determining the headwater depth behind the culvert with road overtopping, to ensure that buildings and other structures are not flooded and that adjacent roadways and adjacent properties do not suffer significantly increased damage during the 100-year storm event. Storage impacts of water behind the culvert may be considered in the calculation, but is not required.

B. Allowable Headwater

The allowable headwater is the depth of water that can be ponded at the upstream end of the culvert during the design condition, as measured from the culvert inlet invert.

The allowable headwater depth shall be limited by the following conditions:

- Headwater does not cause upstream property damage;
- Headwater does not increase the 100-year flood elevation, as mapped by NFIP;
- During a design storm event, the water surface shall be a minimum of 18 inches below the shoulder of the road at the point where the culvert crosses under, or the low point of the road grade where the water would overtop the road;
- Headwater depth shall not exceed 1.5 times the diameter or height of the culvert barrel;
- Headwater depth shall not be such that stormwater flows to other ditches or terrain, which permits the flow to divert around the culvert.
- The maximum overtopping depths during an 100-year storm event for various street classifications are as follows:

9/11/07 6-3 CULVERTS

Classification	Max. Depth at Crown	Max. Velocity
Local	1 ft*	6 fps
Collector	1 ft*	6 fps
Arterial	No Overflow	No Overflow
Highway	No Overflow	No Overflow

- * Street overflow during a 100-year storm will not be allowed if the street is the only means of access for 40 or more residences. A variance to this requirement may be granted if the applicant shows that the connecting roads will be experiencing substantial overtopping during a 100-year storm and that there is no benefit to enforcing this requirement.
- In most instances, the roadway overtopping may be treated as a broad crested weir.

C. Tailwater Conditions

Tailwater is the water into which a culvert outfall discharges. Culvert design shall be based on tailwater conditions that could reasonably be anticipated during the design condition.

- If an upstream culvert outlet is located near a downstream culvert inlet, the headwater elevation of the downstream culvert may establish the design tailwater depth at the upstream culvert.
- If the culvert discharges into a lake, pond, stream, or other body of water, the maximum water elevation of the body of water during the design storm may establish the design tailwater elevation at the upstream culvert.

D. Inlet and Outlet Control

Culvert hydraulic design shall consider both inlet and outlet control conditions. For a culvert operating with inlet control, the flow capacity is governed by the inlet geometry. For an outlet control culvert, the inlet geometry, barrel characteristics and tailwater elevation all impact the flow capacity.

Minimum culvert performance is determined by analyzing both inlet and outlet control for a given flow and using the highest resulting headwater.

(i) Inlet Control

The following factors are considered when calculating inlet control headwater:

• Inlet Area – cross sectional area of the culvert entrance face

• Inlet Edge – projecting, mitered, headwall, or beveled edges are common

• Inlet Shape – rectangular, circular, elliptical, or arch are common

The nomograph for inlet control for circular concrete, corrugated metal and corrugated HDPE culvert pipe is included in Appendix 6A. Nomographs for calculating headwater and flow capacity for other pipe geometries are contained in the VDOT Drainage Manual.

(ii) Outlet Control

The following factors are considered when calculating outlet control headwater:

- Manning's Roughness (n) based on barrel material, for recommended n values, see the table in Appendix 6A.
- Barrel Area cross section perpendicular to the flow
- Barrel Length
- Barrel Slope
- Tailwater Elevation

Outlet control affects the hydraulic grade line of the flow through the culvert. To calculate the hydraulic grade, reference the equations for velocity, velocity head, entrance losses, friction losses, and exit losses contained in the VDOT Drainage Manual.

The nomograph for outlet control on circular concrete and corrugated metal pipe is included in Appendix 6A. For additional nomographs, cross sections, and pipe materials, see the VDOT Drainage Manual.

E. Culvert Velocity

Outlet velocity must be checked to assure that excessive erosion and scour problems will not occur. MS 19 from the VA E&SC Handbook requires that discharges be made to an adequate channel. For discussion of adequate channel requirements, see Chapter 5.

Culvert outlet protection shall be provided in accordance with the standards and specifications for Outlet Protection and Riprap in the VA E&SC Handbook.

Culverts under roads shall be provided with end sections or endwalls in accordance with the outlet protection requirements of the VDOT Drainage Manual.

Where a special design is needed to reduce outlet velocity, it shall be designed in accordance with VDOT standards.

The minimum velocity in a culvert barrel must be adequate to prevent siltation at low flow rates. At a minimum this velocity shall be 3 feet per second for a 2-year storm event.

6.2.4 Structural Design

All culverts shall be designed to withstand a HS-20 highway loading, unless it crosses under a railroad, in which case the culvert shall be designed for railroad loads. The structural design shall consider the depth of cover, trench width and condition, bedding type, backfill material, and compaction.

6.2.5 Materials

Culverts, both public and private, shall be constructed of materials as follows:

- Culverts in the VDOT right-of-way shall be VDOT approved materials in accordance with VDOT IIM-LD-121.15 and VDOT Standard PC-1.
- Public certs not in the VDOT right-of-way shall be:
 - o Reinforced concrete pipe (RCP).
 - o Aluminized corrugated metal pipe (CMP), is allowed for private systems only for sizes 36-inch diameter or smaller. Minimum gage thickness for CMP culverts shall be 16 gage for 30-inch diameter and smaller. Minimum gage thickness for 36-inch diameter CMP culverts shall be 14 gage. Trench design for CMP culverts shall meet ASTM or AASHTO standards.
 - Special CMP culverts including diameters greater than 36-inch, elliptical, and arch designs will be considered on a case-by-case basis by the County of Roanoke for use as culvert pipe material in private storm drain systems.
- Private culverts not in the VDOT right-of-way may be:
 - o RCP or CMP pipe as specified above.
 - Corrugated high-density polyethylene (HDPE) with an integrally formed smooth interior is allowed for sizes 48-inch diameter or smaller. HDPE culvert pipe cover must be in accordance with the County of Roanoke Inspection Specifications for HDPE Pipe.



6.2.6 Culvert Sizes

The minimum culvert size shall be 18-inch diameter, except that culverts under private entrance roads or driveways may be 15-inch diameter if it meets all design flow conditions.

Culverts shall meet all cover conditions required. Where the site conditions preclude the use of a single culvert barrel to meet the design flow conditions, multiple barrel culverts are acceptable.

The maximum length of a culvert shall be 300 feet. A culvert longer than 300 feet shall have manholes or junction boxes and shall fall under the requirements of Chapter 7.

6.2.7 End Conditions

End sections and headwalls shall normally be required on inlets and outlets, as described below.

A. Prefabricated End Sections

Prefabricated end sections, or flared end sections, provide for a better flow path, improving the design flow and headwater conditions.

Prefabricated end sections shall be provided for culverts 18-inch to 36-inch diameter, except:

- No end section is required for 15-inch or 18-inch diameter driveway culverts.
- Where culvert alignment exceeds 20 feet in vertical elevation change or culvert slope exceeds a 2:1 slope, a standard concrete headwall shall be provided instead of a prefabricated end section.
- Where a concrete headwall is provided.

B. Concrete Headwalls and Structures

Precast concrete headwalls shall be provided at all culvert inlets and outlets, unless other end conditions are allowed, as stated above. Precast concrete headwalls shall meet the requirements of the VDOT Standards and VDOT Specifications.

Wingwalls may be required in conjunction with headwalls. Culvert pipes 48" or larger in diameter shall have concrete wingwalls. Wingwalls are generally used where the culvert is skewed to the normal channel flow or where the side slopes of the channel or roadway are unstable. Wingwalls shall meet the requirements of the VDOT Standards and VDOT

Specifications. Wing walls shall be set at an angle between 30 degrees and 60 degrees from the headwall.

Concrete aprons may be used at the entrance or the exit of culvert. Aprons are typically used where high velocities or headwater conditions may cause erosion upstream or downstream of the culvert. An apron shall not protrude above the normal stream bed elevation.

Special design concrete slab end treatment, per VDOT Standards, may be used as a concrete end section.

6.2.8 Multiple Barrel Culverts

Multiple barrel culverts shall be allowed where single culverts cannot handle the design flow while meeting the required cover or headwater condition requirements. The design of multiple barrels should avoid the need for excessive widening of the upstream or downstream receiving channels.

The minimum spacing between culverts in a multiple barrel culvert design shall be that required to provide adequate lateral support and allow proper compaction of bedding material under the pipe haunches.

6.2.9 Culvert Skew

Where possible, culverts shall be installed parallel to the flow path. The maximum allowable skew shall be 45 degrees as measured from the line perpendicular to the roadway centerline.

6.2.10 Buoyancy

Verify that culvert pipe, end sections, and concrete end wall structures will not fail under hydrostatic uplift conditions.

Buoyancy force consists of the weight of water displaced by the pipe and fill material that is over the pipe (below the headwater depth). The force resisting buoyancy includes the weight of the pipe, weight of the water within the pipe, and the weight of fill material over the pipe.

Buoyancy is more likely to be a problem where:

- Lightweight pipe is used
- Pipe is on a steep slope (usually inlet control with the pipe flowing partially full)
- There is little weight on the end of the pipe (flat embankment slopes, minimum cover, and/or no endwalls)
- High headwater depths (HW/D>1.0)

Suitable cover, footings, or anchor blocks may be required to ensure the culvert's integrity during design conditions.

6.2.11 Debris and Trash Racks

In general, trash racks or debris deflectors shall not be used where other site modifications may be made to prevent excessive trash or debris from entering the culvert. However, they may be required at specific locations, by the County of Roanoke, where large amounts of storm debris may be anticipated.

6.3 Installation

All culvert pipe, headwalls, end sections, outlets, and other peripheral structures shall be installed in accordance with VDOT requirements and the manufacturer's recommendations. The characteristics of the trench, bedding, and pipe material all impact the structural strength of the pipe system. The installed culvert conditions shall comply with the design assumptions and calculations.

HDPE pipe installation shall comply with the County of Roanoke's <u>Inspection</u> <u>Specifications for HDPE Pipe</u>. A copy of this installation guide is provided in Appendix 7B.

6.3.1 Bedding Material

Bedding material and installation shall comply with the requirements of the VDOT Specifications.

6.3.2 Backfill

Backfill shall be suitable material and shall be placed and compacted in accordance with VDOT Specifications.

A minimum of 12" backfill shall be placed over the top of a HDPE or CMP culvert prior to placing pavement or other surface treatment.

6.4 Environmental Considerations and Fishery Protection

Where compatible with good hydraulic engineering, a culvert shall be located in "dry" conditions. Where this is not possible, the culvert shall be located to minimize impacts to streams or wetlands

When a culvert is set in a perennial stream the invert of the culvert shall be set below the normal flow line of the stream as required in the VDOT Drainage Manual. The grade of the culvert shall not exceed the grade of the natural stream in the area.

CULVERTS CHAPTER 6

Where construction requires other environmental permits, the applicant shall be responsible for obtaining all necessary environmental permits and complying with their requirements.

6.5 Maintenance Requirements

The permittee is responsible for maintenance of culverts until construction is complete, including final clean up and site stabilization, to the satisfaction of the County of Roanoke. After the completion of construction, the perty owner or responsible party is responsible for maintenance of all culverts not located in public easements.

No one shall modify culverts in any way that impairs or restricts flow. The property owner shall periodically remove silt and sediment from the pipe and prune vegetation around the pipe entrance to avoid restricting flow capacity and shall correct erosion damage as necessary. All removed silt and sediment shall be properly disposed of away from storm drainage pipes and open channels and shall be properly stabilized with vegetation.

APPENDIX 6A

AIDS FOR STORMWATER CULVERT DESIGN

FROM CHAPTER 8, VDOT DRAINAGE MANUAL

Appendix 8B-1, Culvert Design Form LD-269

Appendix 8C-1, Nomograph for Inlet Control for Circular Concrete Pipe

Appendix 8C-2, Nomograph for Inlet Control for Corrugated Metal Pipe

Nomograph for Inlet Control for Corrugated HDPE Pipe

Note: This table is not from the VDOT Drainage Manual.

Appendix 8C-4, Nomograph for Critical Depth, Circular Pipe

Appendix 8C-5, Nomograph for Outlet Control for Circular Concrete Pipe

Appendix 8C-6, Nomograph for Outlet Control for Corrugated Metal Pipe

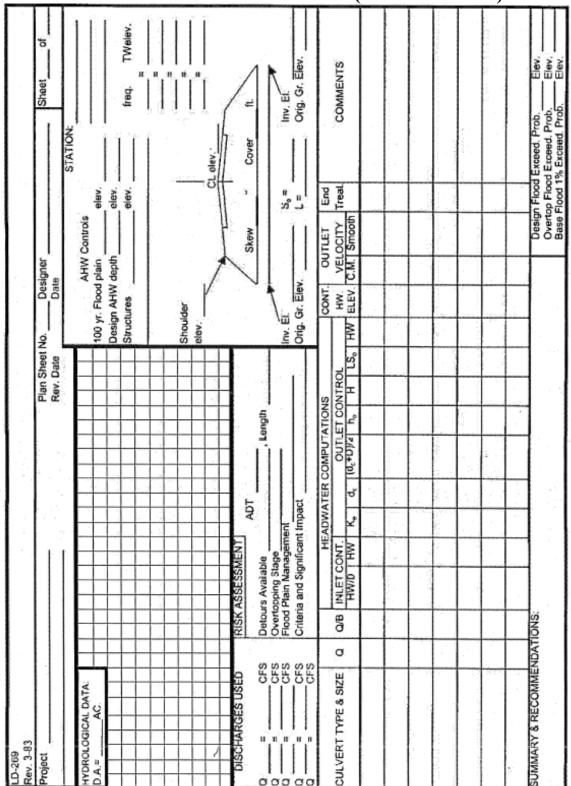
Appendix 8D-1, Recommended Manning's n-Values

Note: This table has been modified from VDOT's standard to include additional pipe materials.

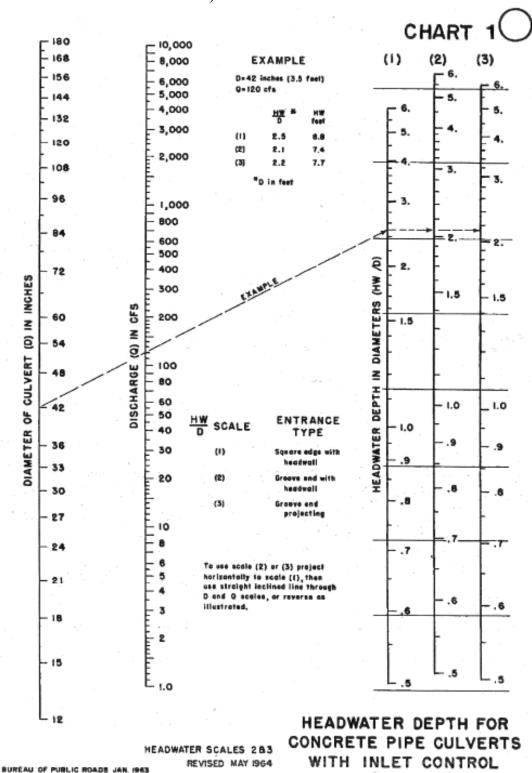
Appendix 8D-2, Entrance Loss Coefficients (K_e), Outlet Control, Full or Partly Full

9/11/07 6A-1 CULVERTS

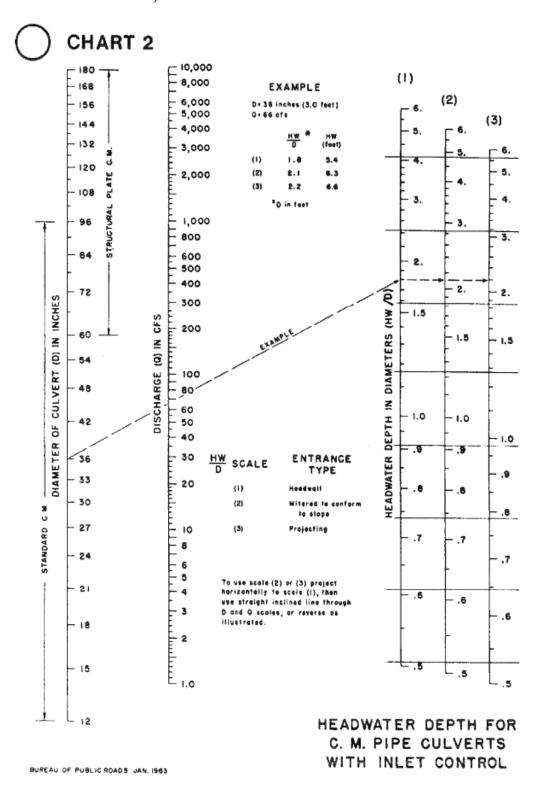
CULVERT DESIGN FORM (VDOT LD-269)



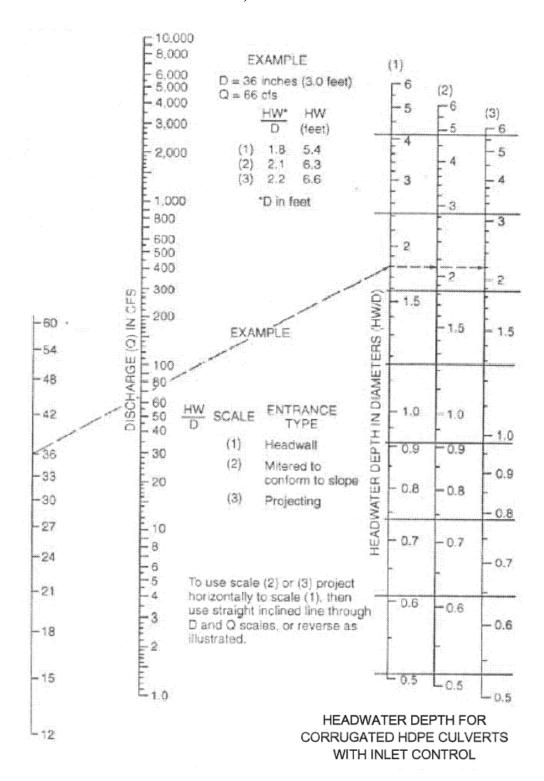
INLET CONTROL, CIRCULAR CONCRETE PIPE



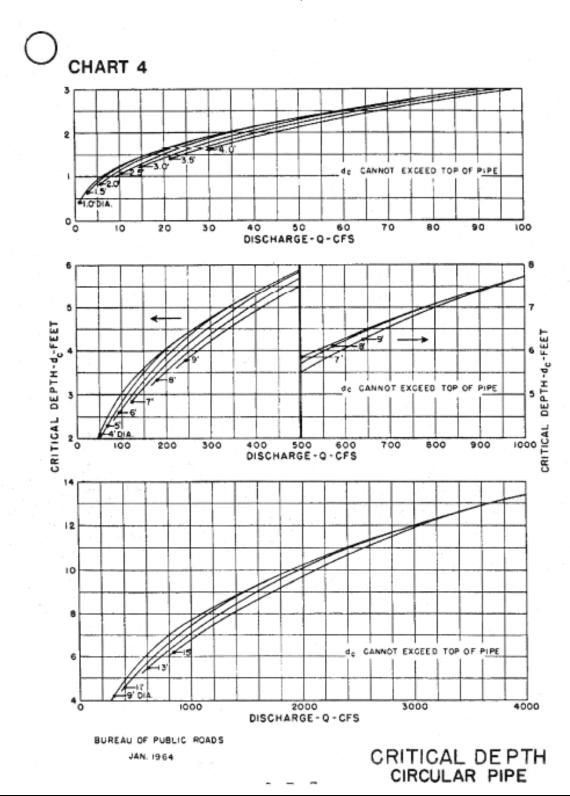
INLET CONTROL, CIRCULAR CORRUGATED METAL PIPE



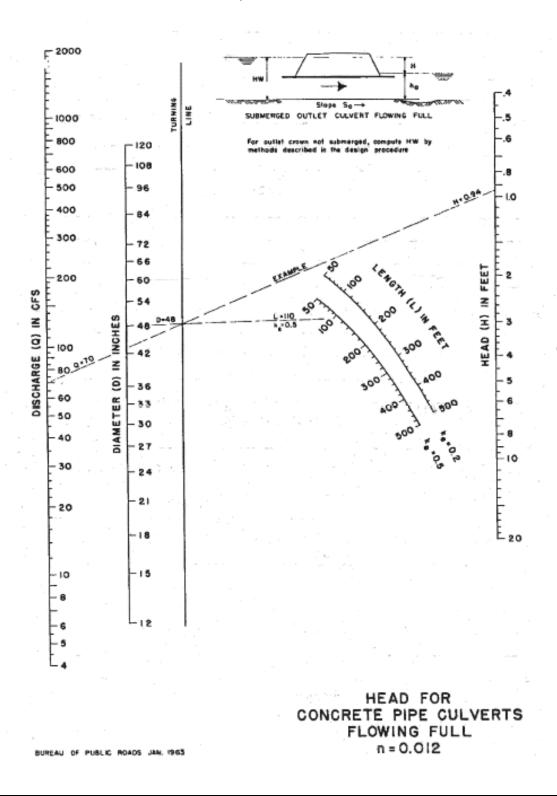
INLET CONTROL, CIRCULAR HDPE PIPE



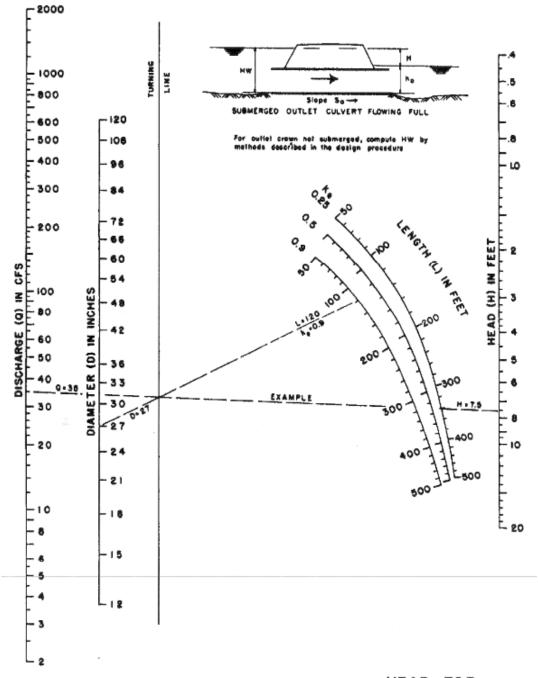
CRITCAL DEPTH, CIRCULAR PIPE



OUTLET CONTROL, CIRCULAR CONCRETE PIPE



OUTLET CONTROL, CIRCULAR CORRUGATED METAL PIPE



SUREAU OF PUBLIC ROADS JAN. 1963

HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n = 0.024

OUTLET CONTROL, CIRCULAR CONCRETE PIPE RECOMMENDED MANNING'S n-VALUES

Type of Conduit	Wall Description	Manning's n
Concrete Pipe	Smooth walls	0.010 - 0.013
Concrete Boxes	Smooth walls	0.012 - 0.015
Corrugated Metal	2 2/3 by ½ inch	0.022 - 0.027
Pipes and Boxes, Annular or	corrugations	
Helical Pipe	6 by 1 inch	0.022 - 0.025
	corrugations	
	5 by 1 inch	0.025 - 0.026
	corrugations	
	3 by 1 inch	0.027 - 0.028
	corrugations	
	6 by 2 inch	0.033 - 0.035
	structural plate	
	9 by 2 ½ inch	0.033 - 0.037
	structural plate	
Corrugated Metal	2 2/3 by ½ inch corrugations	0.012 - 0.024
Pipe		
Spiral Rib Metal	Smooth walls	0.012-0.013
(Steel or Alum.)		
PVC	Smooth interior	0.010 - 0.012
Polyethylene (PE or HDPE)	Smooth interior	0.011 - 0.013
Corrugated PE or HDPE	Corrugated interior	0.022 - 0.026

Note 1: The values indicated in this table are recommended Manning's "n" design values. Actual field values may vary depending on the effects of abrasion, corrosion, deflection, and joint conditions. Concrete pipe with poor joints and deteriorated walls may have "n" values of 0.014 to 0.018. Corrugated metal with join and wall problems may also have higher "n" values, and in addition, may experience shape changes which could adversely affect the general hydraulic characteristics of the culvert.

Note 2: Fore further information concerning Manning n values for selected conduits consult Hydraulic Design of Highway Culverts, Federal Highway Administration, HDS No. 5, page 163.

ENTRANCE LOSS COEFFICIENTS (K_e) OUTLET CONTROL, FULL OR PARTIALLY FULL

Type of Structure and	Coefficient
Design of Entrance	
Pipe, Concrete	0.7
Mitered to conform to fill slope	
End-section conforming to fill slope	0.5
Projecting from fill, square cut end	0.5
Headwall or headwall and wingwall	0.5
Square-edge	0.5
Rounded (radius = $1/12 D$)	0.2
Socket end of pipe (groove end)	0.2
Projecting from fill, socket end (groove end)	0.2
Beveled edges, 33.7° or 45° bevels	0.2
Side or slope-tapered inlet	0.2
Pipe, Corrugated Metal (or Corrugated HDPE)	
Projecting from fill (no headwall)	0.9
Mitered to conform to fill slope, paved or unpaved slope	0.7
Headwall or headwall and wingwall, square-edge	0.5
End section conforming and to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side or slope-tapered inlet	0.2
1 1	
Box, Reinforced Concrete	
Wingwalls parallel (extension of sides),	0.7
square edged at crown	
Wingwalls at 10° to 25° or 30° to 75° to barrel,	
square edged on 3 edges	0.5
rounded on 3 edges to radius of 1/12 barrel	0.2
Wingwalls at 30° to 75° to barrel,	0.2
crown edge rounded to radius 1/12 of barrel	0.2
Side or slope-tapered inlet	0.2

Note:

End Section conforming to fill slope made of metal, concrete, or HDPE, are the sections commonly available from manufacturers. From limited hydraulic test they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections incorporating a closed taper in their design have a superior hydraulic performance. These latter sections can be designed using the information given for the beveled inlet.

Chapter 7 - Storm Drains

A storm drain is a drainage system that conveys water or stormwater, consisting of two or more pipes in a series connected by one or more structures. Storm drains collect and transport stormwater from a site primarily through the use of a closed pipe network. For the storm water to be efficiently handled in a storm drain, the site must also have an efficient way to collect stormwater runoff and have it enter into the piped network. Once in the storm drain, the stormwater is routed to a discharge outfall.

Storm drain systems include:

- Measures to get stormwater runoff to inlets,
- Inlets, and
- storm drain piping and structures that stormwater runoff must pass through to reach the outfall

This section defines criteria and restrictions that shall be used in designing and constructing storm drains. See the VDOT Drainage Manual for more in-depth information.

7.1 References

Except where more stringent requirements are presented in this Manual, storm drain collection systems shall comply with VDOT and DCR requirements. The primary design reference is the VDOT Drainage Manual. Other appropriate references include:

- VDOT Standards
- VDOT Specifications
- VA E&SC Handbook
- FHWA Drainage of Highway Pavements HEC No. 12.
- FHWA Urban Drainage Design Manual HEC No. 22.

7.2 Design Methodology and Criteria

7.2.1 Computation Methods

Computations may be manual or by computer program. Profiles of all storm drain lines 12 inch and larger shall be included on site plans.

Manual computations use design equations and nomographs. Results are documented on VDOT work sheets.

- Form LD-204 Stormwater Inlet Computations
- Form LD-229 Storm Drain Design Computations
- Form LD-347 Hydraulic Grade Line Computations

Copies of these forms are included in Appendix 7A.

There are a number of computer programs available to design storm drainage systems. Any of these computer programs will be acceptable if their methodologies are based on the same equations and nomographs accepted by VDOT, and if they provide the same documentation of inputs, assumptions, and output as are contained on VDOT's work sheets.

Computation methods are explained in detail, including comprehensive design examples, in the VDOT Drainage Manual.

7.2.2 Hydrology

A. Design Flow Methodology

See Chapter 4 for methodology used to determine design flows. Calculations establishing the design flow shall be submitted with the Stormwater Management Plan. Design flows shall be based on ultimate build-out of the contributing watershed based on the current Comprehensive Plan.

7.2.3 Design Flows

The following minimum storm frequencies shall be used:

A. Inlets

Inlets shall be designed for storm frequencies and intensities consistent with the VDOT Drainage Manual. For reference, the VDOT table and its accompanying notes have been included in Appendix 7A.

B. Storm Drains

Storm drains shall be designed for the storm frequencies and intensities consistent with the VDOT Drainage Manual. For reference, the VDOT table and its accompanying notes have been included in Appendix 7A. Unless otherwise specified by the VDOT Drainage Manual or required to convey flow to a stormwater management facility, a 10-year frequency design storm shall be used in developing design flows. If a storm drainage system is conveying stormwater to a stormwater management facility, that is designed to attenuate the 25-year frequency storm,

then the storm drainage system shall be designed for a minimum of a 25-year frequency storm, unless an alternative adequate flow route to the stormwater management facility is present.

7.2.4 Measures to Convey Stormwater Runoff to Inlets

A. Pavement Drainage

One objective in the site design is to collect and remove stormwater runoff from critical areas as efficiently as possible. A properly designed system will ensure that roadways are free of stormwater accumulations, and will protect the public from unnecessary hazards associated with water ponding and sheet flow.

Road pavement shall be sloped transversely to drain stormwater from the roadway. A minimum cross slope of 2 percent should be applied to all roads, both primary and secondary. Greater slope should be considered where poor drainage is anticipated.

Drainage structures associated with medians, curbs, and gutters should be designed to minimize accumulation of water onto travel lanes of roadways.

For additional information concerning drainage of highway pavements, refer to FHWA HEC No. 12.

B. Curb and Gutter

Curb and gutter at the edge of pavements may be used to collect stormwater runoff from roadways. Curbing captures stormwater runoff and directs it to stormwater collection inlets while protecting adjacent properties from flooding and erosion due to sheet flow runoff from the impervious roadways.

A curb and gutter forms a triangular conveyance channel. When a storm occurs, the runoff from the road creates a spread of water from the curb. The curb and gutter must be designed to convey this flow and prevent the spread of water from impacting traffic. The spread width of flow is determined by using nomographs. Nomographs to determine spread width for triangular gutter sections and for VDOT standard curb and gutter are included in Appendix 7A. Nomographs for other composite sections are included in the VDOT Drainage Manual. For curb and gutter flow, a Manning's n value of 0.015 is used in the computational analysis.

Curb and gutter dimensions and design shall meet VDOT Standards.

C. Open Channels

Open channels may be used to collect site drainage and convey it to a storm drain inlet. Design requirements for open channels are covered in Chapter 5.

7.2.5 Storm Drain Inlets

A General

Storm drain inlets are used to collect stormwater runoff from roads, walks, or low elevations during storm events and provide a method for passing the stormwater into the storm drain system. This is usually accomplished by placing storm drain inlets at regular intervals or at key locations to intercept flows and control the stormwater spread width. The design criteria for limiting the spread of water on travel lanes are contained in the VDOT Drainage Manual. The current design table and its notes have been included in Appendix 7A

There are several different types of storm drain inlets which can be used to meet this purpose, and the designer shall choose the proper inlet structure based upon site conditions and design conditions to maximize the drainage efficiencies.

- Curb
- Grate
- Slotted Drain/Trench
- Combination

Stormwater management plans shall include a contour plan with sufficient contours shown to ensure positive drainage to an inlet.

A. Curb Inlets

Curb inlets are vertical openings in the curb covered by a top slab. These inlets can convey large quantities of water, but also allow for large amounts of debris to enter the storm drain system.

Curb inlets shall be used to the maximum extent possible for pavement drainage.

B. Grate Inlets

Grate inlets are horizontal grates usually used in depressed medians or other low elevations. Grate inlets are often referred to as drop inlets or DIs. Grate inlets shall be avoided in paved areas. Where they are used in pavement, inlet grates shall be bicycle safe.

C. Combination Inlets

Combination inlets combine both the vertical opening used by curb inlets and the horizontal grate used in grate inlets. These inlets are often used when the inlet chamber is required to be under the gutter or street pavement away from the sidewalk or other utilities. Combination inlets shall be avoided where possible. Where they are used, they must have bicycle safe grates.

D. Slotted Drain Inlets

Slotted drain inlets are a narrow slotted opening which can collect flow at a median barrier or curb. These inlets are usually located in areas of limited space and can be used to intercept sheet flow, or collect gutter flow to help reduce ponding depth or spreading at grate inlets.

E. Inlet Locations

Inlets shall be located to meet the design requirements of the VDOT Drainage Manual for maximum spread width. In addition, inlets shall be provided, regardless of contributing drainage area as follows:

- Sag points in the gutter grade;
- Upstream of median breaks, crosswalks, and street intersections;
- Immediately upstream and downstream of bridges;
- On side streets at intersections, where flow is approaching the main line;
- Behind curbs, shoulders, or sidewalks to drain low areas or intercept concentrated flow; and
- Any low elevation in the grade.

Inlets shall be avoided in pathways likely to be used by pedestrians or bicyclists.

F. Access

All inlets shall have a removable grate or manhole cover to allow access for clean out.

G. Inlet Capacities

The capacities of each inlet type are contained in the VDOT Drainage Manual. Capacities are determined from equations or nomographs that are contained within the VDOT Drainage Manual. Documentation of inlet capacity shall be made on VDOT Form LD-204, Stormwater Inlet Computations or equivalent.

H. Separation of Pipes

Where two or more pipes enter a concrete structure at or near the same elevation, a 6" minimum horizontal clearance must be maintained between the pipes. Additional clearance between pipes shall be provided if required to protect the structural integrity of the structure.

7.2.6 Storm Drain Pipes

A. Flow Capacity

Based on the size and slope of the storm drain, the design capacity for a pipe flowing full can be determined using Manning's equation.

$$O = A \times 1.49/n \times R^{2/3} \times S^{1/2}$$

Where:

Q = Flow in the pipe (cfs)

 $A = Area of the pipe (ft^2)$

R = Hydraulic radius, for circular pipe R=Diameter/4 (ft)

S = Storm drain slope (ft/ft)

n = Pipe roughness coefficient

The design flow capacity of a storm drain shall comply with the design frequencies set forth in VDOT Drainage Manual as shown in the table in Appendix 7A. In a roadway underpass, or depressed section, where ponded water can only be removed through the storm drain system, a 100-year frequency storm event shall be used to design the storm drain at the sag point.

Storm drain flow capacities shall be documented on VDOT Form LD-229, Storm Drain Design Computations or equivalent form.

B. Storm Drain Slope

To deter the settling of debris and sediment in the storm drain pipe, the pipe shall be designed to ensure positive slope and maintain a minimum velocity of 3 feet per second during a 2-year frequency storm.

maximum pipe velocity in any storm drain shall be 20 ft per second.

Storm drains shall be sloped to meet the velocity requirement set in this chapter. Slopes greater than 16 percent shall be avoided if possible. If unavoidable, drop structures shall be utilized in steeper terrain. In addition, storm drains with slopes steeper than 16% must have anchor blocks for support.

C. Pipe Size

All storm drains located in public easements or rights-of-way shall be a minimum of 15-inch diameter. Pipe size shall not be reduced along the direction of the flow, except as required for proper operation of stormwater management facilities.

D. Access

Regardless of pipe size, a cleanout access point, either an inlet, manhole, or junction box shall be provided at a maximum of every 300 feet of pipe.

E. Water-Tight Joints

The use of water-tight joints is encouraged to prevent infiltration of groundwater, and potential pollutants carried by contaminated groundwater, and to prevent settlement problems from occurring due to soil materials washing into storm drains.

The County rves the right to require the use of water-tight joints in the following locations:

- Under pavement, sidewalks, or concrete structures;
- Through stormwater "hotspots", or other areas where groundwater may be contaminated by pollutants. See Chapter 12 for areas designated as stormwater "hotspots."
- greater than 16 percent.

7.2.7 Determination of Hydraulic Grade Line

A. General

The hydraulic grade line represents the free water surface elevation of water in a pipe system. Where the hydraulic grade line is above the top of a pipe, the pipe is flowing under pressure. The hydraulic grade line in a manhole or other structure is the elevation to which water will rise.

Hydraulic grade lines shall be calculated and evaluated for all storm drains. The hydraulic grade line shall be calculated using VDOT methods and equations that are fully described in the VDOT Drainage Manual. Calculations shall be documented on VDOT Form LD-347, Hydraulic Grade Line Computations, or equivalent. A copy of this form is included in Appendix 7A.

The hydraulic grade line shall not exceed any critical elevation during the design storm. Critical elevations include rising above the ground elevation at inlets or other structures, or reaching an elevation where storm flow could back-up to cause flooding damage.

The calculation of the hydraulic grade line begins at the system outfall and proceeds upstream to each structure on the system. The calculation is based on the principal of conservation of energy as shown below and includes major and minor energy losses:

*JB - Do we want to add some freeboard between HGL and top of structure? $HGL_{us} = HGL_{ds} + H_f + H_m$

Where:

 $HGL_{us} =$ Elevation of hydraulic grade line at the upstream structure $H_m =$ Summation of minor head losses (junctions, bends, etc.)

 $H_f =$ Pipe friction loss

 HGL_{ds} = Elevation of hydraulic grade line at the downstream structure

Major head losses are attributable to friction losses within the pipe. Minor head losses include losses from:

- Junctions
- Exits
- Entrances
- Bends in Pipes
- Access holes
- Conflict pipes
- Plunging flow
- Expansions and contractions
- Appurtenances such as weirs, diverters, valves and meters

B. Outfall Conditions

The hydraulic grade line starts at the system outfall. At this point the hydraulic grade line shall be the actual tailwater elevation or the elevation of 0.8 times the diameter of the outlet pipe, whichever is higher. If the system discharges into a detention or retention pond, the hydraulic grade shall start at the 25 year water surface elevation.

C. Pipe Friction Losses

The friction slope is the energy slope for that run of pipe. The friction slope is determined by inserting pipe information and design flow into Manning's equation and solving for S (slope). The total friction headloss in the run of pipe is the friction slope multiplied by the length of the run.

Where the hydraulic grade line falls below the crown of the pipe, the elevation of normal flow is the hydraulic grade line.

D. Junction Losses

1. General

Junction head losses are the summation of entrance (H_i) , exit (H_o) , and bend losses (H_{Δ}) . When calculating junction losses it is important to use actual flow velocities. If pipes are flowing partially full, then partially full velocities are used.

2. Entrance (expansion) Losses

Entrance loss at a junction is given by:

$$H_i = K_i (V_i^2 / 2g)$$

Where:

 H_i = Entrance head loss

 K_i = Entrance loss coefficient. K_i = 0.35

 V_i = Velocity in the inlet pipe. Where more than one inlet pipe is present, use the velocity from the pipe that has the greatest momentum (Q*V)

 $g = Gravitational acceleration constant, 32.2 ft/s^2$

3. Exit (contraction) Losses

Exit loss at a junction is given by:

$$H_0 = K_0 (V_0^2 / 2g)$$

Where:

 H_0 = Exit head loss

 $K_o = \text{Exit loss coefficient. } K_o = 0.25$, except that $K_o = 0.3$ when computing the loss leaving the initial inlet

 V_0 = Velocity in the outlet pipe.

g = Gravitational acceleration constant, 32.2 ft/s²

4. Bend Losses

Bend loss at a junction are dependent on the angle between the inlet and outlet pipes. If the inlet and outlet pipe are in line with one another no bend) the angle is 0 degrees and there is no bend loss. As the angle increases towards 90 degrees, the bend loss increases. Storm drain

systems should not be designed with bend angles greater than 90 degrees. The bend loss is given by:

$$H_{\Delta} = K (V_i^2 / 2g)$$

Where:

 H_{Λ} = Head loss at bend

K = Bend loss coefficient. K is determined by consulting Figure 9-10 in the VDOT Drainage Manual. A copy is included in appendix 7A.

 V_i = Velocity in the inlet pipe.

 $g = Gravitational acceleration constant, 32.2 ft/s^2$

5. Plunging Losses

Where surface inlet inflow is 20 percent or more of the total flow through a junction, or when a lateral pipe enters a junction with its invert elevation above the crown of the outgoing pipe and the flow in the lateral pipe is 20 percent or more of the total flow through the junction, the total headloss from the structure $(H_i + H_o + H_\Delta)$ shall be multiplied by 1.3 (increased by 30 percent). This adjustment is cumulative with the adjustment for inlet shaping.

6. Inlet Shaping

Inlet shaping refers to how the invert is shaped to provide smooth flow through the structure and is required in all manholes and inlets. When VDOT Standard IS-1, inlet shaping, is used in a structure the total headloss from the structure $(H_i + H_o + H_\Delta)$ shall be multiplied by 0.5 (decreased by 50 percent). This adjustment is cumulative with the adjustment for inlet shaping.

7.2.8 100-Year Conditions

Where there is the possibility of building structures flooding, conditions during the 100-year storm shall be analyzed to verify that all existing and proposed structures do not flood. Flow from the 100-year storm may be carried overland as well as by the storm drain system.

7.2.9 Materials

A. Structures

All stormwater structures (inlets, manholes, and junction boxes) located in public easements or rights-of-way shall be precast or cast-in-place concrete. All structures, frames, grates, and covers shall be in accordance with VDOT Standards and VDOT Specifications.

B. Storm Drain Pipe

Storm drain pipe, both public and private storm drain systems, shall be constructed of materials as follows:

- Storm drains in the VDOT right-of-way shall be VDOT approved materials in accordance with VDOT IIM-LD-121.15 and VDOT Standard PC-1.
- Storm drains not in the VDOT right-of way shall be:
 - o Reinforced concrete pipe (RCP).
 - Corrugated high-density polyethylene (HDPE) with an integrally formed smooth interior is allowed for sizes 48-inch diameter or smaller. HDPE culvert pipe cover must be in accordance with the County of Roanoke <u>Inspection</u> Specifications for HDPE Pipe.

7.2.10 Structural Design

All inlet structures, frames and grates; and pipes shall be designed to withstand a HS-20 loading, unless a pipe crosses a railroad, in which case the pipe shall be designed for railroad loads. The structural design shall consider the depth of cover, trench width and condition, bedding type, backfill material, and compaction.

7.3 Installation

All inlets, pipes, and associated structures shall be installed in accordance with VDOT Specifications and the manufacturer's recommendations. The characteristics of the trench, bedding, and pipe material all impact the structural strength of the pipe system. The installed pipe conditions shall comply with the design assumptions and calculations.

HDPE pipe installation shall comply with the County of Roanoke <u>Inspection</u> <u>Specifications for HDPE Pipe</u>. A copy of this document has been included in Appendix 7B.

7.3.1 Bedding Material

Bedding material and installation shall comply with the requirements of the VDOT Specifications.

7.3.2 Backfill

Backfill shall be suitable material and shall be placed and compacted in accordance with the VDOT Specifications.

A minimum of 12" cover shall be placed over the top of a storm drain pipe prior to placement of pavement or other surface treatment. Additional minimum depth of cover shall be provided if recommended by the manufacturer.

7.3.3 Separation of Utilities

Where storm drains cross other utilities, at least 1-foot of vertical separation shall be provided. Where 1-foot of vertical separation cannot be provided, special provisions shall be made in the bedding and backfill to avoid settlement that could cause point loadings on the storm drain or other utility.

Water lines shall not pass through a storm drain inlet or manhole.

7.4 Environmental Impacts

Construction or modifications to storm drains shall comply with all applicable laws and regulations. The applicant is responsible for procuring all necessary permits.

7.5 Erosion Protection at Outfalls

Erosion protection at storm drain outlets shall be provided in accordance with the outlet protection standards contained in the VA E&SC Handbook and the VDOT Drainage Manual.

7.6 Maintenance Requirements

The permittee is responsible for maintenance of storm drains until construction is complete, including final clean up and site stabilization, to the satisfaction of the County. After the completion of construction, the perty owner or responsible party is responsible for maintenance of all storm drains not located in public easements.

No one shall modify inlets or other structures, pipe entrances, or pipes in any way that impairs or restricts flow. Property owners or responsible party shall periodically remove silt and sediment from the pipes and structures, and prune vegetation from around pipe entrances and inlets to avoid restricting flow capacity and shall correct erosion damage as necessary. All removed silt and sediment shall be properly disposed of away from storm drains, open channels, streams, ponds, and BMPs and shall be properly stabilized with vegetation.

9/11/07 7-12 STORM DRAINS

APPENDIX 7A

AIDS FOR STORM DRAIN SYSTEM DESIGN

FROM CHAPTER 9, VDOT DRAINAGE MANUAL

Table 9-1, Criteria for Inlet Design

Table 9-2, Design Frequencies for Storm Drain Conduit

Notes that accompany Table 9-1 and Table 9-2

Figure 9-10, Losses in Junction due to Change in Direction of Flow Lateral

Appendix 9B-1, LD 204 Stormwater Inlet Computations

Appendix 9B-2, LD 229 Storm Drain Design Computations

Appendix 9B-3, LD 347 Hydraulic Grade Line Computations

Appendix 9C-1, Flow in Triangular Gutter Sections

Appendix 9C-3, Flow Characteristic Curves (24" Gutter)- VDOT Standard

Appendix 9C-23, Manning's Solution for Flow in Storm Drains

Appendix 9C-24, Nomograph for Computing Required Size of Circular Drain for Full Flow

Appendix 9C-25, Concrete Pipe Flow Nomograph

9/11/07 7A-1 STORM DRAINS

CRITERIA FOR INLET DESIGN

R	loadway	Design Speed	Design	Storm	Maximum Design
	ssification	(mph)	Frequency (year ^{1,2})	Intensity (in/hour)	Spread Width ³ (ft)
Princ	ipal Arterial				
,		≤50	10	Actual	Sh. Width +3
With Shoulder	On Grade	>50	10	Actual	Sh. Width
W	Sag Location ⁵	All	10	Actual	Sh. Width +3
der	On Grade	≤50	N/A ⁴	4	½ Driving Lane + Gutter Width (If Any)
Without Shoulder	On Grade ⁵	>50	10	Actual	½ Driving Lane + Gutter Width (If Any)
thout	Sag	≤50	N/A ⁴	4	½ Driving Lane + Gutter Width (If Any)
Wi	Location ⁵	>50	50	Actual	½ Driving Lane + Gutter Width (If Any)
Mino	r Arterial, Col	lector, Local			
ľ	On Grade	≤50	N/A ⁴	4	Sh. Width +3
th	Oli Giade	>50	N/A ⁴	4	Sh. Width
With Shoulder	Sag Location	All	N/A ⁴	4	Sh. Width +3
out lder	On Grade	All	N/A ⁴	4	½ Driving Lane + Gutter Width (If Any)
Without Shoulder	Sag Location	All	N/A ⁴	4	½ Driving Lane + Gutter Width (If Any)

DESIGN FREQUENCIES FOR STORM DRAIN CONDUIT

Roadway Classification	Design Speed (mph)	Design Storm Frequency (year ^{1,2})
Principal Arterial		
With Shoulder	All	25
Without Shoulder	≤50	10
without Shoulder	>50	25
Minor Arterial, Collector, Loca	al	
With or Without Shoulder	All	10

NOTES – CRITERIA FOR INLET DESIGN AND DESIGN FREQUENCIES FOR STORM DRAIN CONDUIT

Notes 1 through 3 are General Notes and should be applied to any functional classification roadway where the site conditions are comparable to the conditions described in each note.

Notes 4 through 5 should normally be applied to the specific locations as noted in the criteria table.

⁴ At location where it may be reasonably anticipated that the runoff from storm events with rainfall intensities greater than 4 inches per hour will overtax the drop inlet system to the point that excess flow will escape the roadway section and result in potential damage to the adjacent property and/or roadway right of way, the drop inlet system shall be analyzed for a check storm event with a rainfall intensity of 6.5 inches per hour.

If all of the runoff from the check storm event is found to be contained within the roadway section, both at the site and down grade, or if runoff escaping the roadway section is found to not be damaging to adjacent property, the drop inlet system may be used as originally designed under the general criteria. If the drop inlet system fails to meet the check storm criteria, it must be re-designed to accommodate the runoff from the check storm event.

9/11/07 7A-3 STORM DRAINS

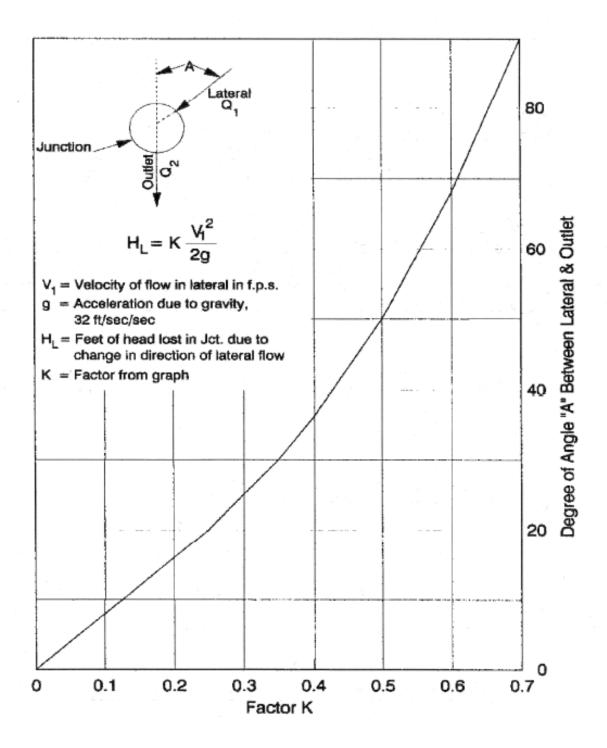
¹ At locations where the vertical alignment of the roadway creates a sag condition in either a depressed roadway section or a roadway section utilizing concrete barriers, and ponded water on the roadway can only be removed through the storm drain system, a 50-year storm frequency and the actual time of concentration should be used as the design criteria for both the drop inlet and the pipe system.

² Federal Flood Insurance criteria dictate that the effects of the 100-year storm event (using the actual time of concentration) on buildings insured under the Flood Insurance Program must be investigated. Such cases should only be encountered where the roadway traverses a designated floodplain area containing insured buildings and the depth of water on the pavement is sufficient to overtop the curb and flow to the buildings.

³ The maximum design spread width may not be obtainable due to the pavement/shoulder slope and the height of the curb. In locations where the curb would be overtopped and water would escape the roadway section prior to achieving the maximum design spread with, the maximum depth of ponded water allowed adjacent to the curb for the design storm shall be curb height minus one (1) inch.

⁵ Drop inlets in these locations are prone to clogging and are often located in areas where maintenance is difficult. To compensate for partial clogging, the computed slot length value should be adjusted by multiplying by a factor of two (2). The adjusted computed slot length value should then be used to determine the slot length specified on the plans.

LOSSES IN JUNCTION DUE TO CHANGE IN DIRECTION OF FLOW LATERAL

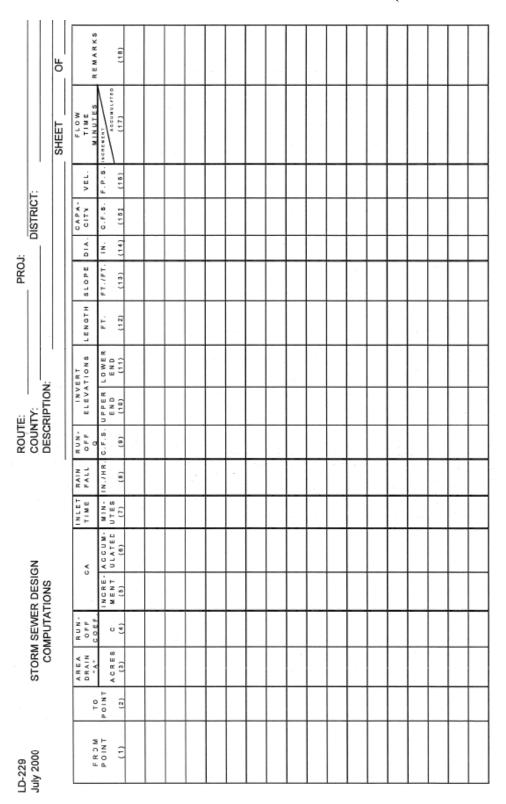


STORMWATER INLET COMPUTATIONS (VDOT LD-204)

				RKS																	
				REMARKS	20							 									
	Į.	(1	T, SPREAD @ SÁG (F	(33)						,											
	ts Or		4/p	(32)																	
ш	Sag Inlets Only		(T=) h	31																	
SHEET OF	Sa		(FT) b	(30)																	
		. (:	Ø₽, CARRYOVER (CFS	(29)										- 1							
		(S	Q _{i,} INTERCEPTED (CF:	(28)																	
			(App. 9C-18)	(27)														1			
			±1/1	(26)													-			-	
		(14	L, SPECIFIED LENGTH ((25)					7.												
Щ.			COMPUTED LENGTH	(24)		ži	-		7		1		,								
DATE		(1:	$S_0 = S_X + S'_W (E_0)$, (FT/F	(23)	<u>,</u>			1	7												
			(VVS1)/6 = W/2	(22)																	
		JE	a = 12W(S _w - S _x) + Loc Depression	(21)								7 1									
			E _o (App. 9C-8)	(20)			L				-								-		
			×S/ MS	(19)	ž									-							
			(TT/FT) _w 2	(18)		100	77				-										
Ι.			T/W	(17)													- 1				
			(TT) W	(16)																	
			T, SPREAD (FT)	(15)																	
		(13	$s_{\rm x}$, CROSS SLOPE (FT/	3																	
		(TH	S, GUTTER SLOPE (FT/	(13)																	
3		(S	o _T , GUTTER FLOW (CF	(12)																	
PROJ		(5	Q _b , CARRYOVER (CF3	£																	
			Q INCR (CFS)	(10																	
			I (IN//HR)	6)																	
			AD mus	8																	
RTE			∀O .	0	,																
			0	9				L							,						
		(;	DRAINAGE AREA (AC	9																	
		L,	NOITATS	4)												-					
10			(FT)	3																	
LD-204 Rev. 6-85	T.	N.E.	34YT	6		,	-			* *	,		1.7	,			- 1	- 1			
LD-204 Rev. 6-8			NUMBER	ε																	

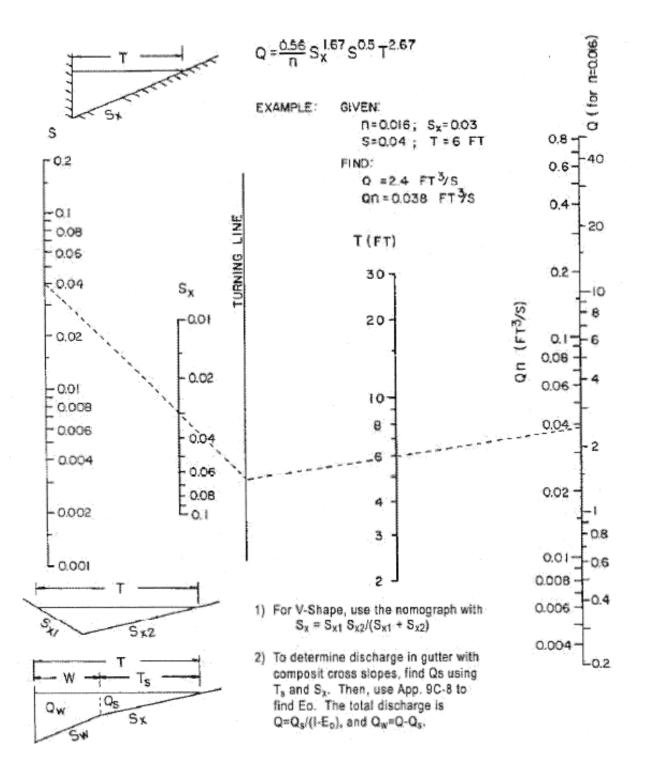
STORM DRAINS

STORM DRAIN DESIGN COMPUTATIONS (VDOT LD-229)

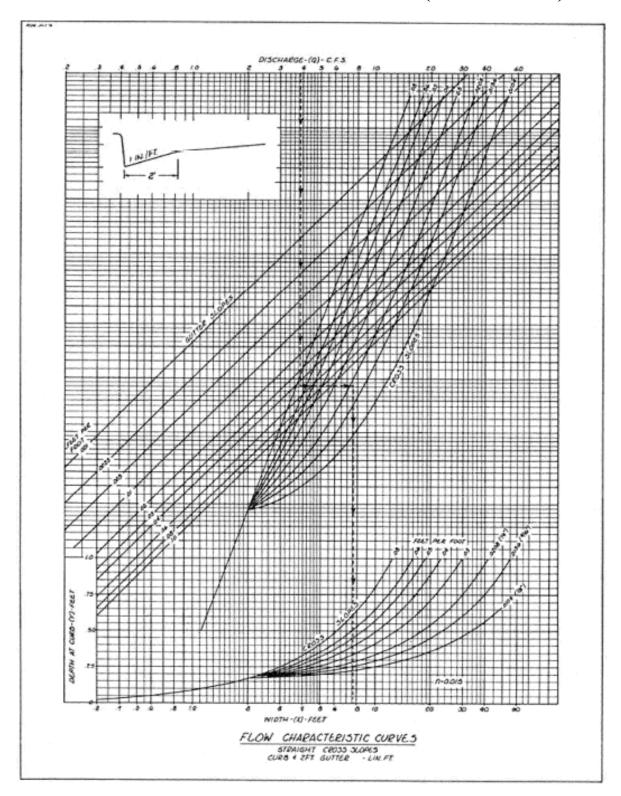


HYDRAULIC GRADE LINE COMPUTATIONS (VDOT LD-347)

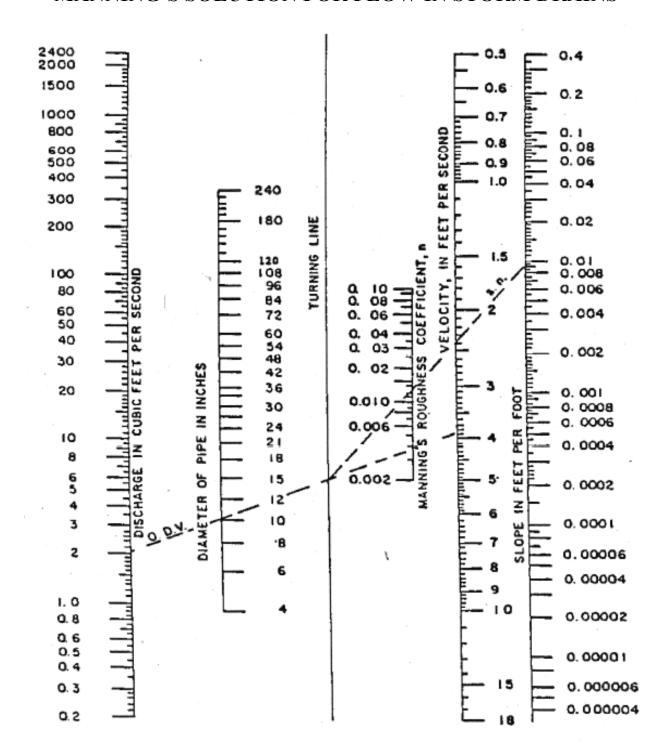
FLOW IN TRIANGULAR GUTTER SECTIONS



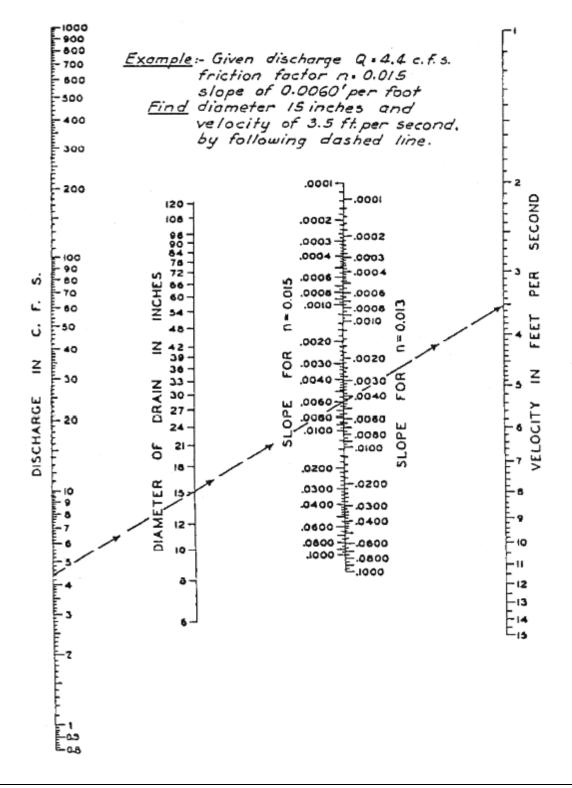
FLOW CHARACTERISTIC CURVES (24" GUTTER)



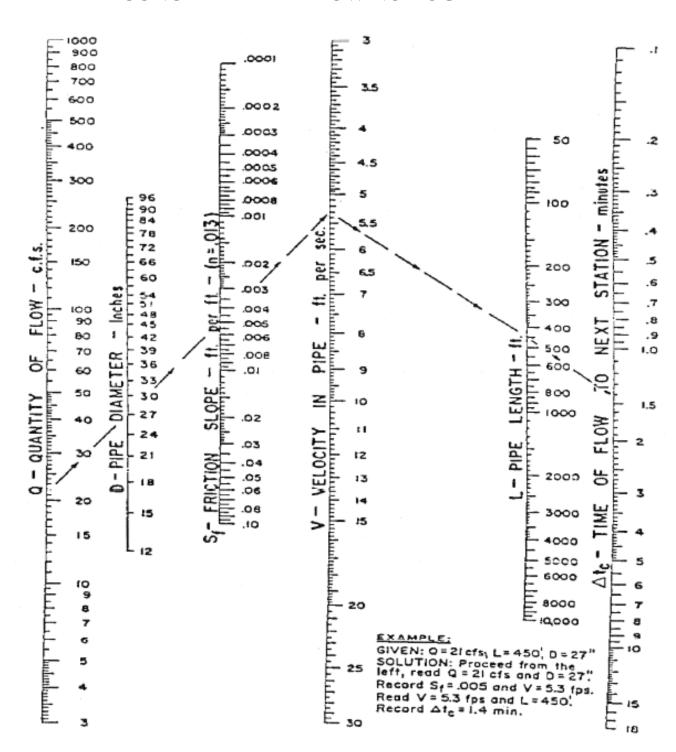
MANNING'S SOLUTION FOR FLOW IN STORM DRAINS



NOMOGRAPH FOR COMPUTING REQUIRED SIZE OF CIRCULAR DRAIN FOR FULL FLOW



CONCRETE PIPE FLOW NOMOGRAPH



APPENDIX 7B

INSTALLATION PROCEDURES

FROM ROANOKE COUNTY

Inspection Specifications For HDPE PIPE

STORM DRAINS

INSPECTION SPECIFICATIONS FOR HDPE PIPE

TABLE OF CONTENTS

- I. Overview
- II. Pre-Installation
 - a. Trench Widths
 - b. Dewatering
- III. Embedment
 - a. Definitions
 - b. Foundation
 - c. Bedding
 - d. Haunching
 - e. Initial Backfill
 - f. Final Backfill
- IV. Joints
- V. Typical Details

2

I. OVERVIEW

The County of Roanoke, in conjunction with the Virginia Department of Transportation, is allowing HDPE pipe for storm sewers. HDPE pipe may be used for any size up to 48" in diameter. Anything above that must use previously approved pipe material.

II. PRE-INSTALLATION

A. Trench Widths

Trench widths used in installing HDPE pipe have been established in AASHTO Section 30 and ASTM D2321. Table 1 provides the recommended trench widths for most installations to provide the proper placement and compaction of backfill material in the haunches around the pipe. Trenching should be completed in the existing soils with sidewalls reasonably vertical to the top of the pipe. When excavation depths or soil conditions require shoring or use of a trench box, the bottom of the shoring or trench box should be placed no lower than the top of the pipe. This prevents disruption of the backfill when shoring of trench box is removed. If this practice cannot be followed, considerations should be given to leaving the shoring in place. Refer to Table 1.

TABLE 1 - SUGGESTED MINIMUM TRENCH WIDTHS

Nominal Pipe Diameter, (in)	Pipe OD (in)	Minimum Trench Width (in)
4	4.78	21
6	6.92	23
8	9.11	25
10	11.36	28
12	14.45	31
15	17.57	34
18	21.2	39
24	27.8	48
30	35.1	66
36	41.7	. 78
42	47.7	. 83
48	52.7	89

3

B. Dewatering

HDPE pipe will float in standing water. Therefore, it is imperative that the trench be dry when installing the pipe. Sump pumps, well points, or other methods may be needed to insure a dry trench.

III.

EMBEDMENT

Embedment materials are those used for the foundation, bedding, haunching, and initial backfill. An illustration of this can be found in Figure 1 page 5.

A. Definitions

- 1. Class I Angular crushed stone or rock (No. 25 or 26 stone).
- 2. Class II Clean, course grained materials, such as gravel, course sands, and gravel/sand mixtures.
- 3. Class III Course grained materials with fines including silty or clayey gravels or sands. Gravel or sand must comprise more than 50% of Class III materials.
- 4. Class IV and V materials are not recommended for embedment materials.

B. Foundation

A stable foundation must be provided in order to insure proper installation. Unsuitable or unstable foundations may be replaced with a suitable bedding material, placed in 6" lifts.

4

C. Bedding

The middle of the bedding, equal to 1/3 of the pipe outside diameter, should be loosely placed. The remaining stone for the bedding should be compacted to a minimum 90% standard proctor density. Class I stone will be acceptable material for use, except when the foundation is in soft, yielding, or otherwise unsuitable material. Then, the bedding material shall be #57 stone for the specified depth, and then capped with 4" of Class I stone.

D. Haunching

Haunching provides the pipe with its main support and strength. Extra care must be taken in installing the haunching. The haunching will extend from the bottom of the pipe up to the spring line. For larger diameter pipes (30"-48"), embedment materials should be worked in by hand. Class I stone may be used and compacted in 8" maximum lifts, compacted to 90% standard proctor density.

E. Initial Backfill

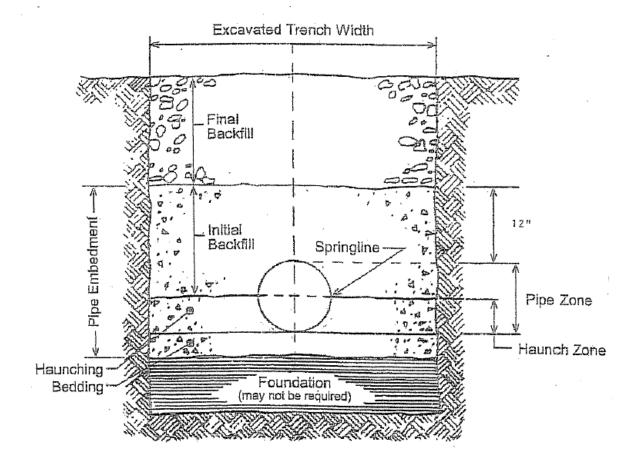
Initial Backfill will extend from the spring line to 12" above the top of the pipe. The backfill material shall consist of Class I stone, compacted in 6" lifts, compacted to 90% standard proctor density.

F. Final Backfill

Final back fill should be the same material as the proposed embankment. Generally, the excavated material will be used for the final backfill. The final backfill is to be placed in 12" maximum lifts, compacted to a minimum 85% standard proctor compaction.

5

Figure 1
Trench Cross Section



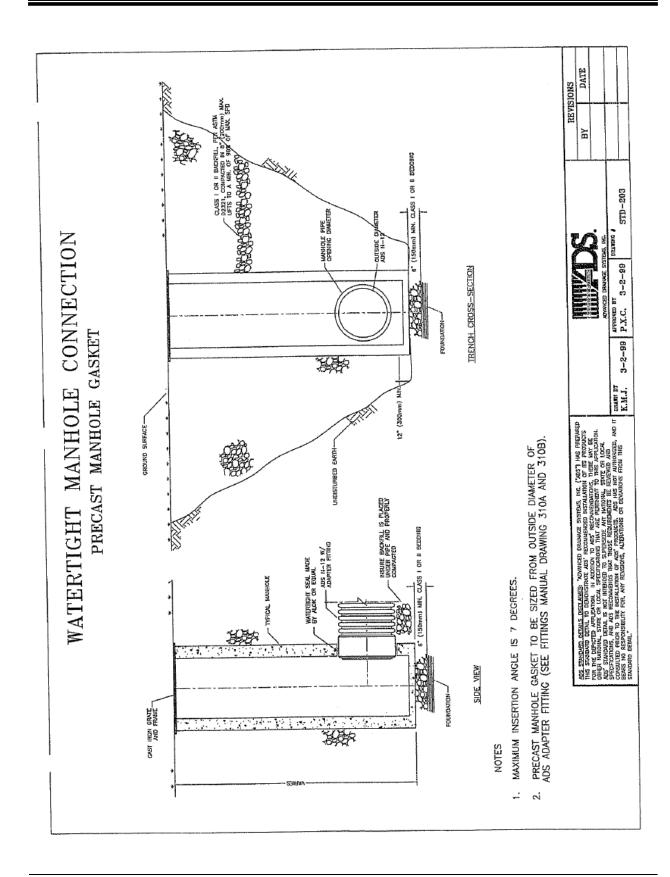
6

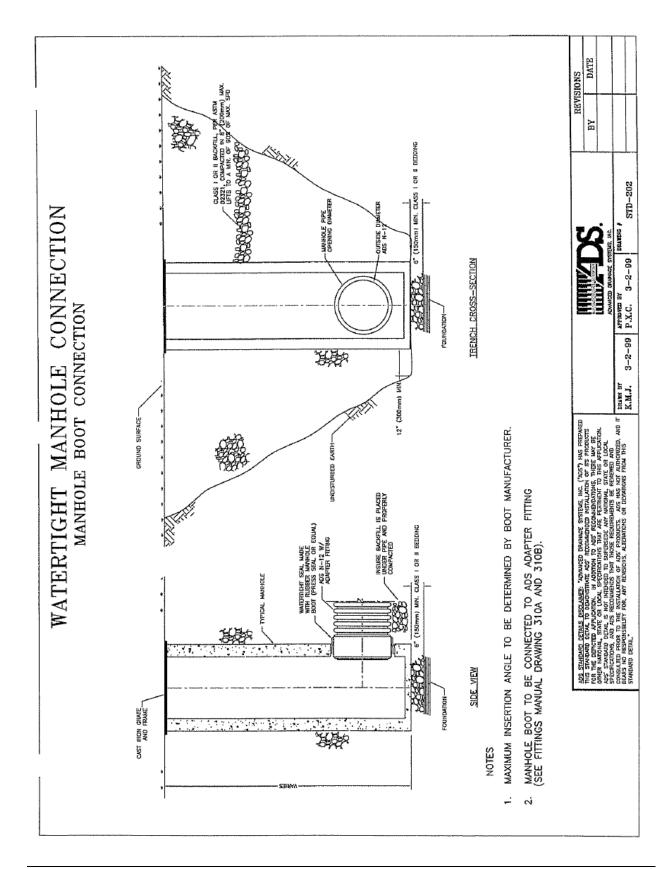
IV. JOINTS

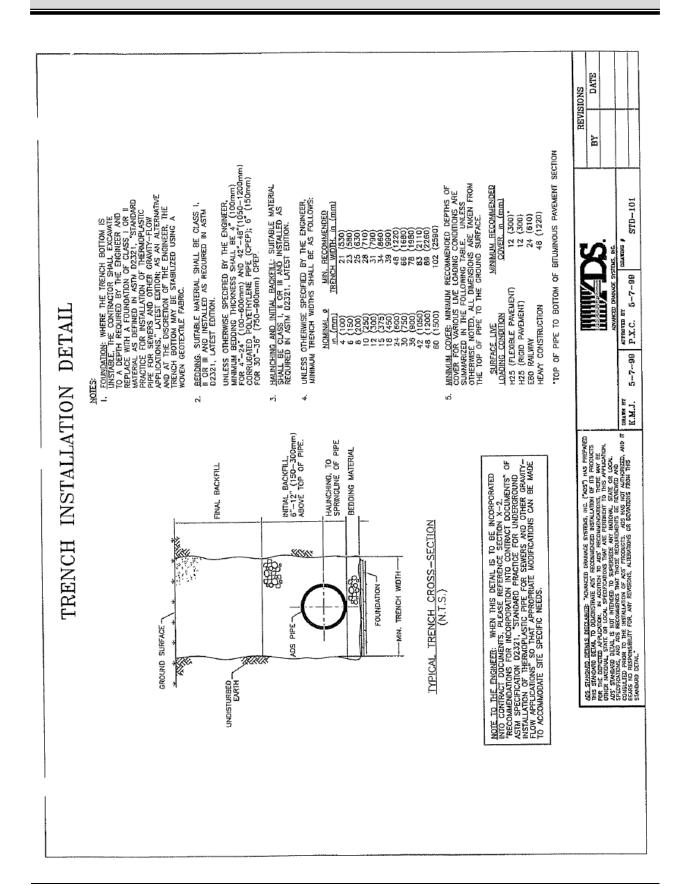
For watertight joints, an ASTM F-477 elastomeric rubber gasket shall be used at all joints of pipe. To install this gasket, the ends of the two pipes being connected shall be cleaned. The gasket shall be applied onto the bell with the marking facing the coupler. Apply lubricant liberally to both joints of the pipes. Align the pipe to push it together on grade. Generally, pipe should be laid from the downstream end and working upstream. Small diameter pies (>24") can be pushed together by hand. Larger diameter pipes may need to use a bar or equipment to push the pipe together. If that is used, a wood block should be used to prevent any damage to the bell of the pipe. Special care should be taken to ensure that no bedding material gets into the joints. Stone or any other material that gets into the joint may cause leaks. Rubber gaskets are normally installed at the factory. However, if a pipe needs to be cut in the field, the gasket shall be stretched over the bell prior to connecting pipes together.

7

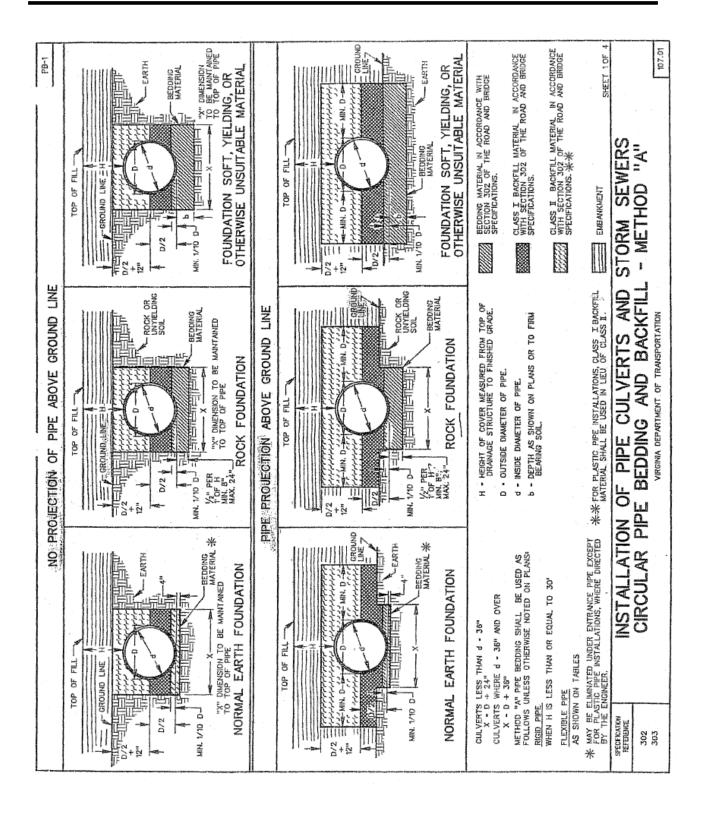
TYPICAL DETAILS AND VDOT TABLES AND DETAILS







POLYETHYLENE CORRUGATED PIPE CULVERT	DIAMETER AREA MAXIMUM COVER (IN.)	0.8 1.5 1.8 3.1 4.9	X 42" 9.6 18	TYPE D OMLY.	NOTE: FOR DETAILS OF BEDDING FOR POLYETHYLENE PIPE CULVERT SEE STANDARD PB-1.	POLIVINI CONCORDE NIBELO PIPE CULVERT	ABEA	(SQ. FT.)	21 2.3 19	24 3.0 H H H H H H H H H H H H H H H H H H H	HOTES: COVER PETCHES PROMICATED BY TABLES ARE FOR FINASHED CONSTRUCTION. TO PROTECT PIPE DURING, CONSTRUCTION, MARKAM PETCHET OF COVER TO BE AS FOLLOWS	PRIOR TO ALLOWING CONSTRUCTION TRAFFIC TO CROSS INSTALLATION,	PIPE DIAMETER MINIMUM COVER HEIGHT DURING CONSTRUCTION 12" TO 30" 1-6"	36" AND ABOVE DIAMETER	MINIMALM FINISHED HEIGHT OF COVER TO BE "/* DIAMETER OR T'-0" WINCHEVER IS CHEALER. EXCEPT FIPE UNDER ENTRANCES AND MEDIAN CROSSOVERS WIÆRE A 9" MRINNUM WILL BE PERMITTED FOR PIPE UP TO 24" DIAMETER.	•• THE COVER SHALL EXTEND THE FULL LENGTH OF THE PIPE. THE APPROACH FILL IS TO EXTEND A MANALM OF TODICHMETER: 1/2 DIAMETERS ON EACH SIDE OF THE STRUCTURE, OR TO THE WITERSECTION WITH A CUT.	THE ALLOWABLE COVER TABLES SHOWN ARE BASED ON A SOR, MODILLUS OF 700 PSI. ALL OTHER DESIGN CRITERIA ARE, IN ACCORDANCE WITH THE AASHTO SPECIFICATIONS AND VDOT MODIFICATIONS FOR SOIL THERMOPLASTIC PIPE DITERACTION SYSTEMS.	PLASTIC PIPE	LAY AND PLASTIC PIPE	TABLE FOR H-20 I
		!	-		-	:		,				06	RAMP OF THE	PIPE UNDER	OHS UNLESS				VITRIFIED CL	COVER
	CLAY PIPE	ALLOWABLE MAXIMIM COVER IFT.)	15	ž	S.	52	32	13	מ		IS TO BE EXTRA STRENDTH. YER SHOWN IN TABLE ARE ION,	ON MINISTUR HEIGHT	COVER PROBE TO ALLOWING CONSTRUCTION I MARTE TO CHOSS TRAILLAIGN IS TO BE 3.0 FT. THS COVER IS TO EXTEND THE FIRL LENGTH OF THE PIPE CUVERT. THE APPROACH FILL RAMP IS TO EXTEND A MAKING OF DIDIALALOY ON EACH SIDE OF THE	MANAGAM ENISHED HEIGHT OF COVER TO BE 2.0' EXCEPT PIPE UNDER REFRANCES AND MEDIAM CROSSOVERS WHERE A 9" MANAGAM WILL	DE FERMATIES METHOD "A" BEDDWID IS TO BE USED FOR ALL NISTALLATIONS UNLESS DIHERWISE DESIGNATED ON PLANS.			VITRIFIED CLAY	VIT	MAXIMUM
	RENGTH	AREA (SQ. FT.)	9.0	1.2	1.8	2.4	3.1	4,9	7.1		IS IO BE EXTRA STRENGT VER SHOWN IN TABLE ARE HON,	CONSTRUCT	NG CONSTRUCTOR FILE (F. CULVERT. OF IDIDIA + 1	OF COVER TO	TO BE USED IN			VITR		45
	EXTRA ST	DIMMETER (BV.)	12	15	18	21	24	30	36		NOTES: ALL VITREED CLAY PIPE: WAXIMUM HEIGHTS OF COV FOR FINGSHED CONSTRUCT	T PIPE DURING	DR TO ALLOWII DN IS TO BE 3 TH OF THE PIP END A MIRMUM	AND MEDIAN (C. BEDDWG IS DESIGNATED O				1 JC 11	
PC-1	L	:				I					NOTES: ALL VITRIFIE WAXIMUM HE FOR FINISHE	TO PROTEC	COVER PRICE PRICE PRICE PRICE LENGTH FULL LENGTH FOR EXTE CULVERT, OR	ENTRANCES	METHOD "A				SPEET 16	REV. 7701



Chapter 8 - Residential Lot Drainage (RESERVED)

Chapter 9 – Stormwater Detention

Stormwater detention facilities are a means of attenuating increases in peak flows caused by land development. In addition to providing flood control, stormwater detention facilities can protect downstream channels from increases in erosion and provide a measure of water quality treatment. This chapter addresses general requirements for detention facilities as they relate to attenuating peak flows. Chapter 11 addresses the use of detention facilities as water quality BMPs.

When a storm event occurs, stormwater runoff enters the detention facility. The outlet structure allows a portion of the stormwater runoff to discharge from the facility and the remainder of the stormwater runoff is temporarily stored. After the end of the storm, water continues to discharge from the facility until it is empty.

Stormwater detention facilities include:

- Detention Basin
- Retention Basin
- Extended Detention Basin
- Enhanced Extended Detention Basin
- Underground Detention

A detention basin is a pond that is normally dry. When a storm event occurs, it temporarily stores stormwater runoff, discharging it at a controlled rate through a hydraulic outlet structure to a downstream conveyance system.

A retention basin is a stormwater pond which includes a permanent pool, even during non-rainfall periods. The pond includes storage above the normal pool elevation which temporarily stores stormwater runoff during storm events.

An extended detention basin is a pond which temporarily stores runoff for a specific time period following a storm event, discharging it at a controlled rate through a hydraulic outlet structure to a downstream conveyance system. An extended detention basin is dry during non-rainfall periods. An extended detention basin provides more protection to the downstream channel from increases in erosion than a detention basin by releasing stored runoff at a lower rate over a longer time period. A typical plan and profile for an extended detention basin are detailed in the VA SWM Handbook.

An enhanced extended detention basin is similar to an extended detention basin, but it also incorporates a shallow marsh in its bottom to provide additional quality treatment which is discussed in Chapter 11.

An underground detention facility consists of pipes or manufactured underground chambers used to temporarily store stormwater runoff following a storm event, discharging it at a

controlled rate through a hydraulic outlet structure to a downstream conveyance system. An underground detention facility is dry during non-rainfall periods.

In addition to detention and retention basins, the design requirements specified by this chapter shall apply to ponds created as private property amenity features and farm ponds.

9.1 References

Except where more stringent requirements are presented in this Manual, the design and construction of stormwater detention facilities shall comply with VDOT and DCR requirements. The primary design references are:

- VA SWM Handbook
- VDOT Drainage Manual
- VA E&SC Handbook
- VDOT Standards

9.2 Design Methodology and Criteria

9.2.1 Hydrology

See Chapter 4 for methodology used to determine design flows.

9.2.2 Design Flows and Storage Volumes

To properly design stormwater detention facilities, a flow routing program shall be used with an appropriate elevation – discharge - storage relationship for the design storm events.

9.2.3 Minimum Contributing Drainage Area

A stormwater retention basin, which contains a permanent pool, requires at least 10 acres of watershed drainage and/or a good source of base flow to maintain the permanent pool. A minimum drainage area of 20 acres shall be used when the basin is located in an area of high visibility to prevent unsightly drying of the permanent pool. Retention basins are best suited for regional and large drainage area projects.

9.2.4 Detention Facility Locations

Stormwater detention facilities should not be constructed within a Federal Emergency Management Agency (FEMA) designated 100-year floodplain. If this is unavoidable, the facility

shall comply with all applicable regulations under the National Flood Insurance Program, 44 CFR Part 59.

The following factors shall be addressed when siting a stormwater detention facility:

- Geotechnical conditions including soil conditions;
- Groundwater levels and it's potential impacts;
- Karst topography;
- Existing and proposed utilities;
- Aesthetics on surrounding properties; and
- Environmental impacts including wetlands.

Stormwater basins shall be located to minimize the aesthetic impacts to the surrounding property. Basins shall be set back from property lines a distance equal to the minimum width of the applicable required buffer yard.

Locate stormwater detention facilities to avoid collecting significant amounts of drainage from offsite areas.

Stormwater basins shall be set back at least fifty feet from a residential dwelling structure as measured from the wall of the structure to the top of the basin embankment. In proposed single family residential subdivisions, the stormwater management facility shall be located in a single non-developed lot.

9.2.5 Basin Grading

Stormwater basins shall be graded to blend into the surrounding topography with the following conditions:

- Basin side slopes shall be no greater than 3:1.
- Provisions shall be made for the long-term maintenance of basin slopes and periodic access for maintenance of the outlet structure, emergency spillway, and removal of accumulated sediments.
- The maximum allowable depth of a stormwater detention basin shall be 15 feet, as measured from the top of the embankment to the lowest point in a basin.

• The bottom of the basin shall have a low flow or pilot channel to facilitate complete drainage. The pilot channel shall convey flows from a 2 year storm event and prevent standing water during dry-weather conditions. The pilot channel shall be sloped a minimum of 2% if it is a grass-lined channel and at a minimum of 1% if concrete-lined.

In addition to the above requirements, the follow standards of practice should be used when designing a stormwater basin to the extent possible:

- The length-to-width ratio of a stormwater basin should be a minimum of 2:1. A 3:1 ratio is desired where possible. This prevents short-circuiting of the basin's storage areas.
- To minimize cut and fill, the long dimension of a stormwater basin should run parallel to the contours.

9.2.6 Embankments and Emergency Spillways

Stormwater basin earthen embankments shall be designed and constructed to maintain structural integrity during the 100-year frequency storm event. When applicable, Virginia Dam Safety regulations shall apply.

The minimum top width of an embankment shall be 10 feet. Width may be greater based on the overall height. Embankment side slopes shall be no steeper than 3:1. Embankments with an emergency spillway must provide at least one foot of freeboard from the maximum 100 year storm water surface elevation to the top of the embankment. An embankment without an emergency spillway must provide at least two feet of freeboard from the maximum 100 year storm water surface elevation to the top of the embankment.

A geotechnical study shall be required for all stormwater basins with constructed embankments greater than 6 feet in height as measured from the base of the embankment. See Chapter 13 for requirements of a geotechnical report.

9.2.7 Outlet Structures and Release Rates

A. Stormwater Release Rates

Stormwater detention facilities shall be designed with an outlet structure to control the release rate from stormwater being held in the facility. Design release rates shall meet the requirements set forth in Chapter 4, except that extended detention facilities shall be designed based on releasing the design storm runoff volume in a prescribed time as indicated in the VA SWM Handbook.

All stormwater detention facilities shall be empty within 72 hours following the storm event.

Farm ponds and ponds created as private property amenity features shall be exempt from release rate requirements.

B. Outlet Structure Criteria

Outlet structures generally include a principal spillway or outlet and an emergency overflow. An outlet structure may take the form of a drop inlet, pipe, weir, or orifice. The principal spillway or outlet is intended to release flow from the design storm events at the necessary controlled rate, without allowing flow to enter the emergency spillway or overflow. The sizing of the outlet structure shall be based on the results of the hydrologic routing calculations or model. Due to the tendency of clogging, the minimum orifice diameter shall be 3 inches.

Outlets from stormwater detention facilities shall be designed to function without manual, electrical, or mechanical controls.

Where necessary, energy dissipaters shall be placed at the outfall to provide a non-erosive velocity from the facility to a channel. See Chapter 10 for the design of outfall protection.

Where a stormwater basin with an earthen embankment does not have an emergency spillway, the principal outlet or spillway shall be sized to safely pass the flow from the 100-year frequency storm without over topping the earthen embankment. In this instance, the design of the primary outlet structure shall include a 50% clogging factor during the 100-year frequency storm as a safety factor. When the primary spillway is less than 24 inches wide, it shall be considered inoperative during a 100-year frequency storm.

For examples of design calculations of outlet structure orifices and weirs, see the VDOT Drainage Manual and VA SWM Handbook.

All riser structures shall be cast-in-place or precast concrete, unless a substitute material has been approved by the County. VDOT standards for riser structures may be found in the VDOT Standards.

Outlet pipes shall be reinforced concrete pipe with rubber gasket watertight joints, shall have appropriate seepage control, and shall be installed on a concrete cradle from the tie of the pipe to the riser for the entire length of the outfall pipe. Concrete cradle shall be in accordance with the requirements of the VDOT Standards.

C. Adequate Channel

Outflows from stormwater detention facilities shall be discharged to an adequate channel. For adequate channel requirements, see Chapter 5.

9.2.8 Water Quality

When designed appropriately, stormwater detention facilities may provide a measure of pollutant removal which can be used to meet the water quality standards in the regulations. For water quality requirements and standards, see Chapter 11.

9.2.9 Landscaping

Stormwater basin embankments shall be vegetated. Selection and plant installation shall be in accordance with the standards of the VA SWM Handbook. Trees and shrubs shall not be planted within a stormwater detention basin, nor on a stormwater basin berm, dam, or emergency spillway.

The VA SWM Handbook shall be utilized for guidance for landscaping in the marsh areas of enhanced extended detention basins.

Native plants will be used to the maximum extent possible.

9.2.10 Underground Detention

A. Materials

All materials used in underground detention facilities shall be corrosion resistant consisting of reinforced concrete, aluminized corrugated metal pipe, corrugated high density polyethylene pipe, or similar approved material.

B. Slope

Underground detention facilities shall be sloped to drain at a minimum floor slope of 1 percent.

C. Capacity

Underground detention facilities shall be sized such that the 100-year design storm may be routed through the facility with no damage to the surface property.

D. Accessibility and Maintainability

All underground detention facilities shall be designed to be readily accessible for periodic inspection and maintenance from the surface without the need to perform confined space entry.

Providing pre-treatment to remove sediments before or at the entrance of the underground detention facility to improve water quality and/or improve maintainability should be considered during the design.

9.2.11 Trash Racks

Outlet structures shall be equipped with an appropriate trash rack. The trash rack shall be in accordance with the VA SWM Handbook.

9.3 Environmental Impacts

Environmental impacts shall be carefully considered when siting stormwater detention facilities. Siting basins in low lying areas with potentially environmentally sensitive areas requires careful consideration, coordination, approval, and permitting with local, state, and federal agencies to evaluate the suitability of constructing in these areas. Environmentally sensitive areas include, but are not limited to wetlands, shallow marshes, jurisdictional waters, natural watercourses, wildlife habitat, etc. and may be protected by state and/or federal laws. With careful planning, it may be possible to incorporate wetland mitigation into the basin design.

Construction of stormwater basins or modifications to existing basins shall comply with all applicable laws and regulations. The applicant is responsible for procuring all necessary permits, such as US Army Corps of Engineers and Virginia DEQ Wetland Permits, Virginia DEQ VPDES Permits, VSMP Permits, etc., prior to beginning construction.

Detention facilities shall be coordinated with a watershed or regional plan for managing stormwater runoff, if available.

9.4 Maintenance Requirements

For the post-construction maintenance of stormwater detention facilities, see Chapter 14.

Chapter 10 - Energy Dissipation

Outlet protection for culverts, storm drains, BMP outlets, and steep open channels is essential to preventing major erosion from damaging downstream channels and drainage structures. Erosion problems at culverts or at the outlet from detention basins are a common occurrence. Determination of the flow conditions, scour potential, and channel erosion resistance shall be standard procedure for all designs.

Outlet protection can be a channel lining, structure, or flow barrier designed to lower excessive flow velocities and prevent erosion and scour.

Outlet protection shall be employed whenever the velocity of flow at a pipe or open channel outlet exceeds the erosive velocity of the immediate downstream reach.

Energy dissipation may take the form of the following:

- Erosion control stone-lined channels;
- Riprap outlet basins; or
- Concrete baffled outlets.

10.1 References

Except where more stringent requirements are presented in this Design Manual, energy dissipators shall comply with VDOT and DCR requirements. The primary design references are the VDOT Drainage Manual and the VA E&SC Handbook. Other appropriate references include:

- VDOT Standards
- FHWA Design of Riprap Revetment HEC No. 11 (Pub. No. FHWA-IP-89-016 1989/2000)
- FHWA Hydraulic Design of Energy Dissipators for Culverts and Channels HEC No. 14 (Pub. No. FHWA-EPD-86-110 Sept. 1983 & FHWA-IF-00-02 2000)
- U.S. Dept. of the Interior Bureau of Reclamation: Hydraulic Design of Stilling Basins and Energy Dissipators (Engineering Monograph No. 25)
- U.S. Dept. of the Interior Bureau of Reclamation: Design of Small Canal Structures

10.2 Design Methodology and Criteria

10.2.1 Outlet Velocity

Where the outlet velocity from culverts, storm drain outfalls, or open channels is high, and channel or pipe modifications cannot adequately reduce the velocity, energy dissipation may be necessary.

For the calculation of open channel velocity, see Chapter 5.

For the calculation of exit velocity from culverts, see Chapter 6.

For the calculation of exit velocity from storm drain pipes, see Chapter 7.

10.2.2 Erosion Control Stone

The most common form of energy dissipation is the use of erosion control stone at the outlet. Protection is provided primarily by having sufficient length and flare to dissipate energy by expanding the flow. The outlet velocities are computed for the design discharge and the 25-year discharge. Whichever velocity is the highest is used for energy dissipation design.

Where a pipe discharges into a channel, the apron shall extend across the channel bottom and shall extend up the bank to a depth of one foot above the maximum tailwater depth from the design storm event. The dimensional requirements of the erosion control stone apron shall be determined using the graphical curves in the VA E&SC Handbook.

Generally, the use of erosion control stone for energy dissipation is limited to a maximum velocity of 19 feet per second. Alternative means of energy dissipation shall be required where the discharge velocity is greater than 19 feet per second. Alternative means include riprap outlet basins or concrete baffled outlets. The use of alternative means of energy dissipation requires the approval of VDOT when located in a VDOT right-of-way.

10.2.3 Riprap Outlet Basins

A riprap basin is a depressed area of riprap placed at the outlet of a high velocity culvert, storm drain outlet or open channel. The riprap reduces the exit velocity by expanding the flow over the riprap length and width and forming a hydraulic jump.

For the design of riprap basins, refer to the VDOT Drainage Manual. Dissipator geometry may also be computed using the "Energy Dissipator" module that is available in the computer program FHWA HY8, Culvert Analysis.

Details of the riprap basin energy dissipator are included in Appendix 10A.

10.2.4 Baffled Outlets

A baffled outlet usually consists of a concrete box structure with a vertical hanging concrete baffle and an end sill. Several variations of concrete baffled outlets have been published by VDOT and other state and local transportation and stormwater management agencies. A typical schematic of baffled outlets are shown in Appendix 10C. Baffled outlets are usually used when very high exit velocities exist at piped or channel transitions. Baffled outlets function by dissipating energy through impact of the water hitting the baffle and through the resulting turbulence. A tailwater depth is not required for adequate energy dissipation, but will help smooth the outlet flow.

This type of outlet protection may be used with outlet velocities up to 50 feet per second.

Baffled outlets are not included in the VA SWM Handbook. Hydraulic design procedures may be found in the U.S. Department of Interior, Bureau of Reclamation, <u>Design of Small Canal Structures</u>, 1978 and are as follows:

Step 1: Determine input parameters, including:

H = Energy head to be dissipated, feet (can be approximated as the difference between channel invert elevations at the inlet and outlet).

Q = Design discharge, cubic feet/second

v = Theoretical discharge velocity determined from 2 g H, feet/second

 $A = Flow area, Q / v, feet^2$

d = Flow depth entering the basin, ft

Fr = Froude number = $v / (g d)^{0.5}$, dimensionless

g = Gravitational constant = 32.2 feet/second²

Step 2: Calculate the minimum basin width, W, in feet, using the following equation:

$$W / d = 2.88 (Fr)^{0.566}$$

Where:

W = minimum basin width, feet d = depth of incoming flow, feet Fr = Froude number = $v / (g d)^{0.5}$ The limits of the W/d ratio are from 3 to 10, which corresponds to Froude numbers 1 to 9. If the basin is much wider than W, flow will pass under the baffle and energy dissipation will not be effective.

Step 3: Calculate other basin dimensions as a function of W,

Refer to the Schematic of Baffled Outlet in Appendix 10CA for other dimensions as a function of W and to identify variables that are used below in other steps.

Step 4: Calculate the required protection for the transition from the baffled outlet to the natural channel based on the outlet width.

A riprap apron shall be added of width W, length W (or a 5-foot minimum), and depth f (W/6). The side slopes shall be 1.5:1, and the median rock diameter shall be at least W/20.

Step 5: Calculate the baffled outlet invert elevation based on the expected tailwater.

The maximum distance between expected tailwater elevation and the invert should be b+f or some flow will go over the baffle with no energy dissipation. If the tailwater is known and fairly controlled, the baffled outlet invert should be a distance (b/2) + f below the calculated tailwater elevation. If tailwater is uncontrolled, the baffled outlet invert should be a distance f below the downstream channel invert.

Step 6: Calculate the outlet pipe diameter entering the basin assuming a velocity of 12 fps flowing full.

Step 7: If the entrance pipe slopes steeply downward, the entrance pipe shall be turned horizontal for at least 3 feet before entering the baffled outlet.

Step 8: If it is possible that both the upstream and downstream ends of the pipe will be submerged, provide an air vent approximately 1/6 of the pipe diameter near the upstream end to prevent pressure fluctuations and possible surging flow conditions.

10.2.5 Energy Dissipator for Paved Areas

For energy dissipation from velocities from paved channels or flumes, use VDOT Standards. Schematics of energy dissipators for paved flumes has been included in Appendix 10C.

10.2.6 Additional Energy Dissipators

For additional energy dissipators, refer to FHWA HEC No 14 entitled, Hydraulic Design of Energy Dissipators for Culverts and Channels.

10.3 Installation Requirements

Energy dissipators shall be installed and constructed according to all applicable FHWA, VDOT, and DCR requirements and recommendations.

10.4 Easements

Where an energy dissipater will be owned by a public jurisdiction or agency, a drainage easement must encompass the entire energy dissipator, and provide an additional area 10 feet wide around the entire energy dissipator to provide for maintenance.

10.5 Environmental Impacts

Construction or modifications to energy dissipation structures shall comply with all applicable laws and regulations. The applicant is responsible for procuring all necessary permits, such as US Army Corps of Engineers and VA DEQ Wetland Permits, VA DEQ VPDES Permits, etc.

10.6 Maintenance Requirements

The permittee is responsible for maintenance of energy dissipation structures until construction is complete, including final clean up and site stabilization, to the satisfaction of the County. After the completion of construction, property owners or responsible parties are responsible for maintenance of all energy dissipation structures located in private easements.

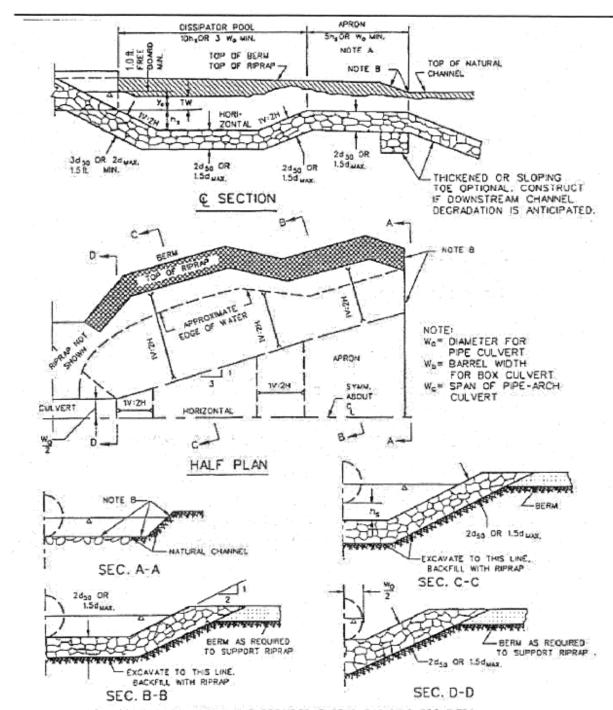
APPENDIX 10A

AIDS FOR ENERGY DISSIPATION DESIGN

FROM VDOT DRAINAGE MANUAL

Figure 8E-1, Details of Riprap Basin Energy Dissipator

Figure 8E-3, Riprap Basin Design Checklist



- NOTE A IF EXIT VELOCITY OF BASIN IS SPECIFIED, EXTEND BASIN AS REQURIED TO OBTAIN SUFFICIENT CROSS-SECTIONAL AREA AT SECTION A-A SUCH THAT Q_{des}/(CROSS SECTION AREA AT SEC. A-A) = SPECIFIED EXIT VELOCITY.
- NOTE B WARP BASIN TO CONFORM TO NATURAL STREAM CHANNEL. TOP OF RIPRAP IN FLOOR OF BASIN SHOULD BE AT THE SAME ELEVATION OR LOWER THAN NATURAL CHANNEL BOTTOM AT SEC. A-A.

Figure 8E-1. Details of Riprap Basin Energy Dissipator

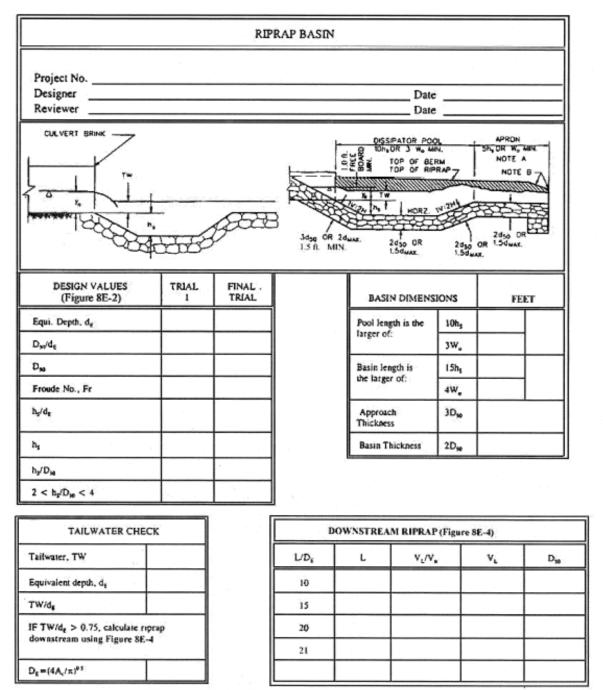


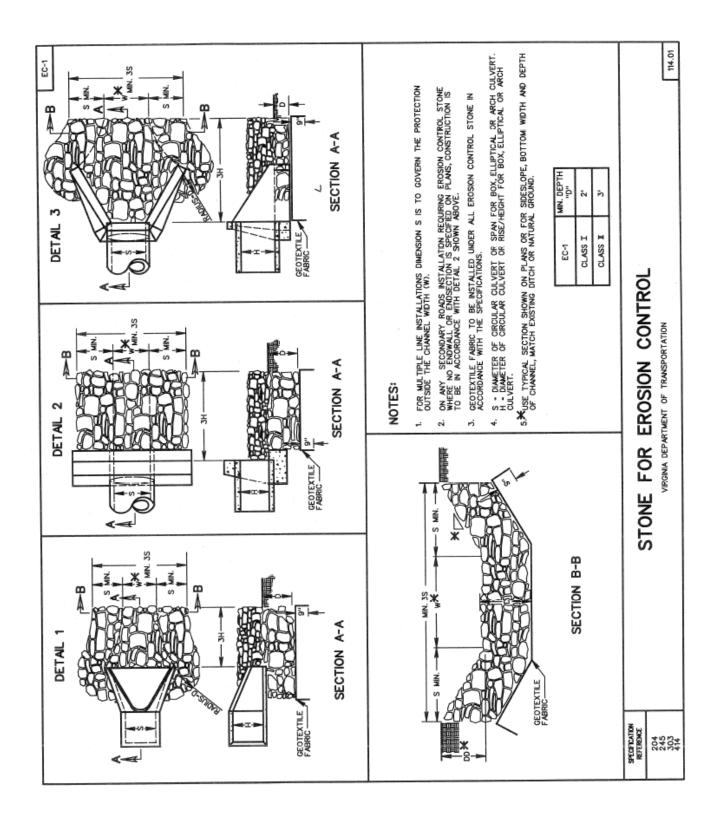
Figure 8E-3. Riprap Basin Design Checklist

APPENDIX 10B

AIDS FOR ENERGY DISSIPATION DESIGN

FROM VDOT ROAD AND BRIDGE STANDARDS

Standard 114.01, Stone for Erosion Control



APPENDIX 10C

ENERGY DISSIPATION DESIGN SCHEMATICS

Schematics of Baffled Outlet, from US Bureau of Reclamation, Design of Small Canal Structures (as used by the State of Georgia and State of Colorado)

Standard Energy Dissipator for Use with Paved Flume, from VDOT Road and Bridge Standards

Precast Energy Dissipator, from VDOT Road and Bridge Standards

Various Energy Dissipators and Stilling Basins, from City of Knoxville, TN BMP Manual

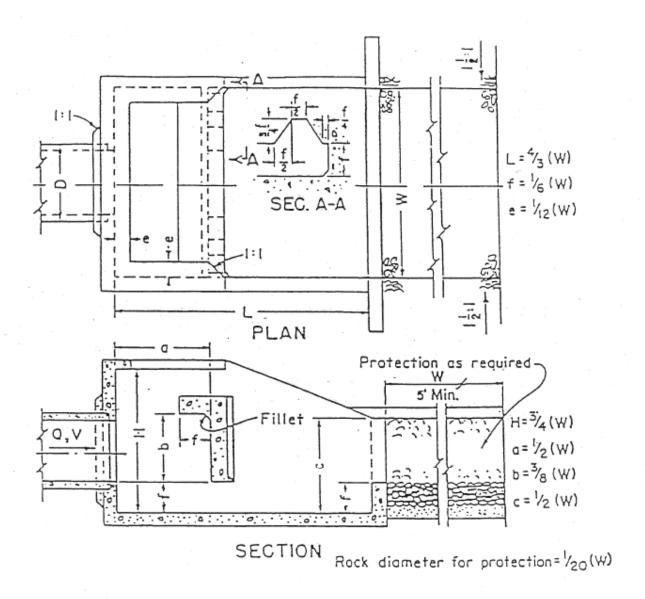


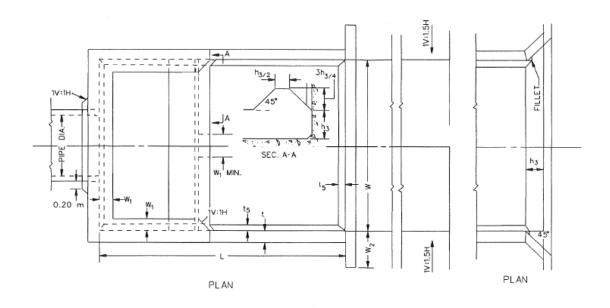
Figure 4.5-11 Schematic of Baffled Outlet (Source: U.S. Dept. of the Interior, 1978)

4.5-22 Georgia Stormwater Management Manual

Volume 2 (Technical Handbook)

CDOT Drainage Design Manual

Energy Dissipators



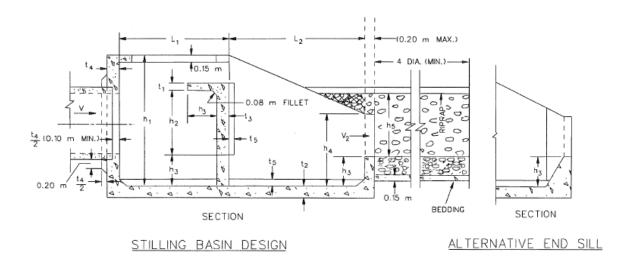
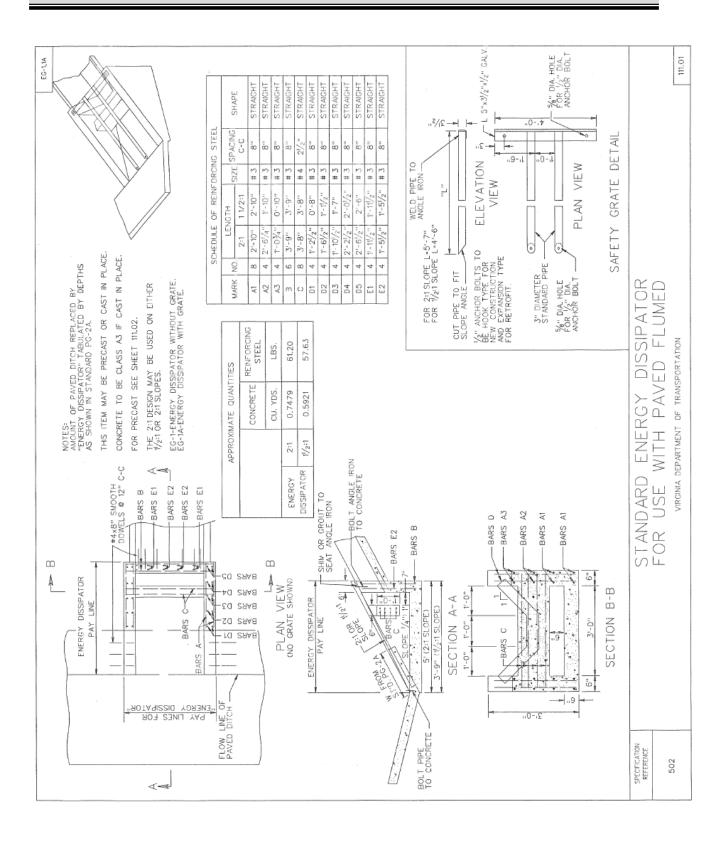
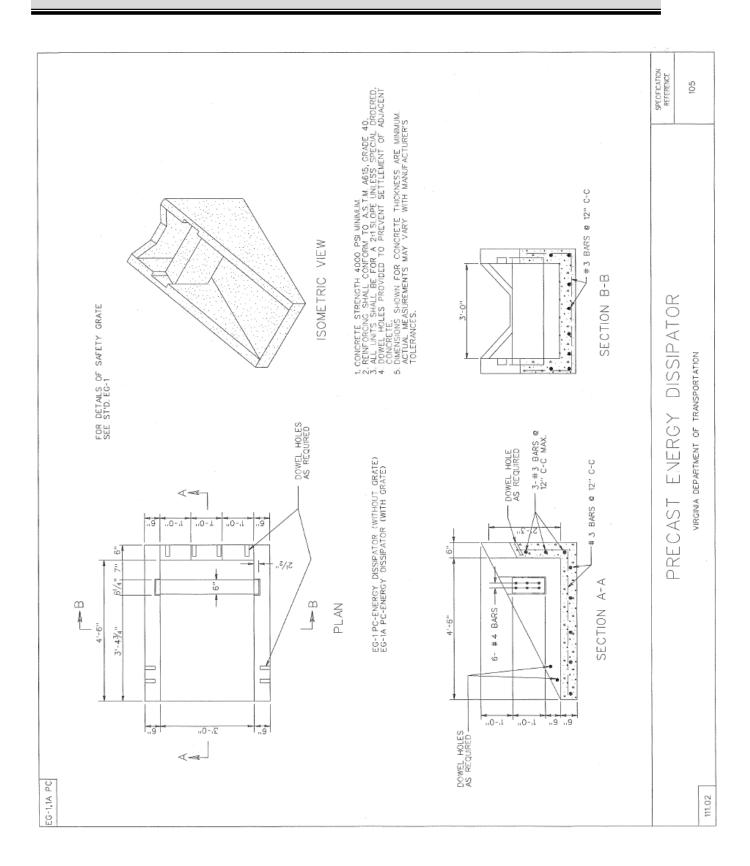


Figure 11.7 USBR Type VI (Impact) Dissipator

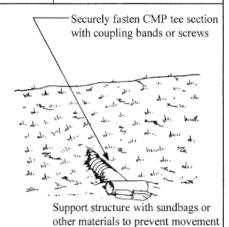




adequate freeboard End sill (may be dentated)

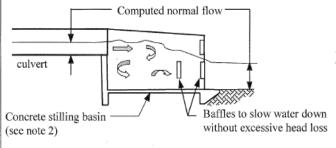
Chute blocks (size and shape vary) Baffle piers, optional, see note 1 (size and shape vary) Sufficient depth for hydraulic jump plus

Typical Stilling Basin At End of Paved Flume or Chute

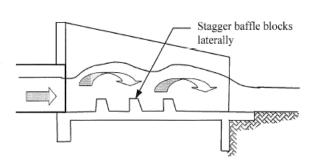


ES - 25

Temporary CMP Energy Dissipator



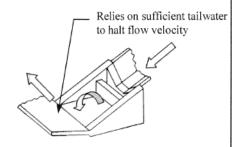
Typical Stilling Basin Using Baffles and Elevation Drop



<u>Typical Energy Dissipator - Baffle Blocks Within Headwall</u>

Notes:

- This is the basic format for several types of stilling basins. USBR Type II basin does not contain baffle piers, but does have a dentated end sill. USBR Type III basin has baffle piers and a smooth undentated end sill. See HEC-14 for detailed design of concrete structures.
- Concrete stilling basin should be approximately as wide as the downstream channel. Design baffles to retain sufficient stormwater to act as a plunge pool for a wide range of flow values.



Typical Impact Energy Dissipater (Virginia DOT)

NOT TO SCALE

Figure ES-25-2 Various Energy Dissipators and Stilling Basins

Chapter 11 - Stormwater Pollutant Removal Practices

A wide variety of Best Management Practices (BMPs) and general development strategies may be utilized to remove environmentally harmful pollutants from stormwater runoff. The practices discussed in this chapter are constantly evolving, and developers and designers are encouraged to use the most up to date procedures and practices to prevent pollutants from entering and dispersing into the surface and ground waters.

11.1 References

Except where more stringent requirements are presented in this Design Manual, stormwater quality best management practices shall comply with DCR requirements. The primary design reference is the VA SWM Handbook. Other appropriate references include:

- VA E&SC Handbook.
- Center for Watershed Protection: Better Site Design An Assessment of the Better Site Design Principles for Communities Implementing Virginia's Chesapeake Bay Preservation Act.
- Low-Impact Development Design Strategies: An Integrated Design Approach Prince George's County, MD Department of Environmental Resources Programs and Planning Division.
- Center for Watershed Protection: The Architecture of Urban Stream Buffers Watershed Protection Techniques.
- Metropolitan Washington Council of Governments: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs,

11.2 Stormwater Quality Requirements

Stormwater runoff generated from land disturbing activities shall be treated through best management practices designed to remove pollutants from the stormwater. The required pollutant removal shall be dependent on the land cover conditions. Compliance with the water quality criteria may be satisfied by applying either performance-based criteria, or technology-based criteria to the stormwater runoff generated from the site.

For most projects, the BMPs will be designed to remove phosphorus from the stormwater runoff. Generally, when a BMP is efficient in removing phosphorus from the stormwater runoff, it is assumed that easier to remove pollutants such as heavy metals and total suspended solids have also been adequately removed.

Where appropriate, depending on the site, additional pollutants may be required to be removed from the stormwater runoff. These pollutants may include:

- Total Suspended Solids, in areas with highly erodible soils
- Total Petroleum Hydrocarbons (TPH), fueling stations or areas with fuelcontaminated soil
- Heavy Metals, in areas with contaminated soils

Land disturbing activities shall also comply with all additional water quality requirements as indicated in the Erosion and Sediment Control and Stormwater Management Ordinance of Roanoke County, Virginia.

Proposed residential subdivisions or commercial or industrial parks shall apply stormwater quality management criteria to the land development project as a whole. Individual lots in new subdivisions shall not be considered separate land development projects, but rather the entire subdivision shall be considered as a single land development project. Hydrologic parameters shall reflect the ultimate land development and shall be used in all engineering calculations.

Where stormwater quality requirements must be implemented, stormwater runoff from all impervious surfaces must flow through appropriate BMPs before the water is discharged from the site.

11.3 Stormwater Quality Calculations

To meet the requirements of this Chapter, BMP selection may be based on performance-based criteria or technology-based criteria.

11.3.1 BMP Selection Using Performance-Based Criteria

BMP selection is based on a calculation of the total phosphorus that must be removed to provide post-development runoff pollutant levels that do not exceed pre-development runoff levels. Once the total pollutant removal quantity is determined, a BMP, or multiple BMPs may be selected for a site to meet the water quality pollutant removal that is required.

For land disturbing activities, the calculated post-development non-point source pollutant runoff is compared to the calculated pre-development non-point source load based on the average land cover condition or the existing conditions. The non-point source pollutant runoff load or "pollutant discharge" is defined as the average amount of a particular pollutant(s) measured in pounds per year, delivered in a diffuse manner by stormwater runoff.

The accepted calculation procedure for the determining the pre- and post-developed pollutant loads is the Simple Method. The Simple Method uses impervious cover as the key variable in calculating the levels of pollutant export.

The VA SWM Handbook includes a detailed summary of the calculation procedure. The procedure uses phosphorus as the target contaminant for the purposes of calculating pollutant discharge in order to determine compliance with the performance-based water quality criteria.

A more detailed discussion and derivation of the Simple Method can be found in Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, published by the Metropolitan Washington Council of Governments.

Calculations shall be submitted documenting compliance with the stormwater management requirements. The submitted calculations shall document:

- The applicable area (A), and post-development impervious cover (I_{post}).
- The existing pre-development impervious cover (I_{existing}) or if the standard average land condition value of 16 percent will be used.
 - When determining existing conditions, the calculations may consider the
 site conditions which have existed for up to 5 years prior to the project.
 For example, if a building were on a site and was demolished 2 years prior
 to the proposed redevelopment, the existing impervious cover may include
 the building as a part of the existing impervious cover conditions.
- Determination of the appropriate development condition.
- The pre-development pollutant load (L_{pre}) .
- The post-development pollutant load (L_{post}).
- The pollutant removal requirement.
- The BMPs proposed and how the pollutant removal requirement will be met.

For guidance through this calculation method, worksheets have been prepared by DCR matching each of these steps. These worksheets and associated tables for completing the calculations have been included in Appendix 11A.

The selection criteria for choosing an appropriate BMP at any given development site is often dictated by the physical characteristics of the site, such as soil types, topography, and drainage area. The pollutant removal requirement for the site may dictate that a BMP with a high removal efficiency be used, while the physical characteristics of the site may dictate that a combination of strategically located BMPs be used.

Table 11.1 includes a listing of BMPs, currently approved by DCR and their corresponding performance based removal efficiencies.

Table 11.1 Phosphorus Removal Efficiencies

Water Quality BMP	Phosphorus Removal Efficiency	Percent Impervious Cover
Vegetated Filter Strip	10%	16-21%
Grassed Swale	15%	
Constructed Wetlands	20%	22-37%
Extended Detention (2x WQV)	35%	
Retention Basin I (3x WQV)	40%	
Bioretention Basin	50%	38-66%
Bioretention Filter	50%	
Extended Detention-Enhanced	50%	
Retention Basin II (4x WQV)	50%	
Infiltration I (1x WQV)	50%	
Sand Filter	65%	67-100%
Infiltration II (2x WQV)	65%	
Retention Basin III (4x WQV with Aquatic Bench)	65%	

^{*} Innovative or alternate BMPs not included in this table may be allowed at the discretion of the County. Innovative or alternate BMPs not included in this table which target appropriate non-point source pollution other than phosphorus (such as petroleum, hydrocarbons, sediment, etc.) may be allowed at the discretion of the local program authority.

The County will consider alternate structural BMPs not included in Table 11.1, on a case-by-case basis. If an alternate structural BMP is proposed, the applicant shall provide ample evidence of the pollutant removal efficiency of the proposed structural BMP. Submittal information may include the following information:

- Evidence of approval of the proposed BMP by DCR at the proposed pollutant removal efficiency rate.
- Technical information including drawings, specifications, maintenance requirements, manufacturer's catalog information, peer reviewed removal efficiency studies performed in conditions similar to those present in the Roanoke region, regulatory approvals, and other necessary information such that the County has reasonable assurance of the effectiveness of the BMP.

In all cases the local program authority shall be contacted to determine if options are available in the local program as a result of a watershed or regional BMP plan.

11.3.2 BMP Selection Using Technology-Based Criteria

The performance-based method is based on calculations and is the most widely accepted method for meeting the water quality requirements. However, the water quality requirements may also be met by utilizing technology-based criteria in which the stormwater BMP selection is based solely on the percent of impervious area of the land after the land disturbing activity has been completed. Using the proposed impervious percentage, Table 11.1 is consulted to select an appropriate BMP.

The selected BMP shall be located, designed, and maintained to perform at the target pollutant removal efficiency specified in Table 11.1. Detailed design standards and specifications for the BMPs in Table 11.1 are available in the VA SWM Handbook.

11.3.3 Water Quality Volume (WQV)

Water quality volume (WQV) is used to properly size BMPs and other storage structures. By definition the WQV is equal to the volume from the first ½ inch of stormwater runoff from all the impervious surfaces passing through the BMP.

11.4 Non Structural BMPs

Non-structural BMPs include measures that can be taken to reduce impacts to stormwater quality by implementing source control practices. In some cases, it may be more cost-efficient to prevent stormwater pollutants from entering the storm drainage system than to design, implement, and maintain structural designs to reduce the levels of pollutants once they have already impacted the stormwater. If used properly, non-structural BMPs can be effective in controlling these pollutant impacts.

The applicant is encouraged to meet with County personnel (Planning Department, Engineering Department, etc.) during the project concept phase to discuss implementation of any single or combination of non-structural practices to reduce the quantity or pollutant loading in the stormwater runoff.

The primary benefit of utilizing non-structural BMPs is to gain a reduction of impervious area of the land-disturbing activity or development project. By reducing the impervious area, the quantity of pollutant runoff may be lessened, reducing the post-development pollutant rate, WQV, size, or number of structural BMPs required to meet the Stormwater Management Ordinance. Additional credit for utilizing non-structural BMPs to control stormwater runoff and water quality leaving the site may be considered on a case-by-case basis by the County dependent on the documented effectiveness of the proposed measure submitted by the applicant.

Proposed non-structural BMPs should be identified in acceptable technical literature, or be deemed acceptable by sound professional judgment and should have documented benefits on stormwater quality. Additional information and references to various non-structural BMPs can be found in Better Site Design - An Assessment of the Better Site Design Principles for Communities Implementing Virginia's Chesapeake Bay Preservation Act, 2000, published by the Chesapeake Bay Local Assistance Department.

11.5 Structural BMPs

11.5.1 General Selection Criteria Information

BMPs shall be chosen based on the physical conditions of the site and the required pollutant removal requirements. Physical site conditions that shall be considered include:

- Topography, Terrain Features, and Slopes
- Drainage Area
- Depth to Water Table
- Soils and Geotechnical Conditions
- Hydraulic Head
- Location to Environmentally Sensitive Features
- Proximity to Building Foundations and Other Structures

Table 11.1 has been published by DCR detailing various BMP selections and the projected pollutant removal capacity for each BMP. To receive stormwater quality credit, the BMP must be constructed and maintained to DCR standards as detailed in the VA SWM Handbook. The following sections summarize the design criteria for structural BMPs which are acceptable in meeting the water quality requirements. However, the VA SWM Handbook should be consulted for detailed requirements.

The following minimum requirements must be met for all structural BMPs:

- 1. All structural facilities shall be designed so that the specific required storm frequency storage volumes are met.
- 2. If hydrologic or topographic conditions warrant greater control than that provided by the minimum control specifications, the County reserves the right to impose any and all additional requirements deemed necessary to protect downstream properties and aquatic resources from damage due to increased volume, frequency, and rate of stormwater runoff.
- 3. Due to regional geology and soil conditions, stormwater infiltration BMPs may not be applicable for many sites in the Roanoke Valley. Thus, stormwater infiltration practices, or practices having an infiltration component will not be allowed unless

- the applicant provides sufficient evidence based on field investigations that an infiltration BMP will work as designed.
- 4. All BMPs shall be maintained in accordance with the requirements contained in Chapter 14.

11.5.2 Vegetated Filter Strip

Vegetated filter strips, also called vegetated buffer areas, are vegetated areas in which overland runoff is routed to reduce velocities and filter pollutants. By reducing the velocity, suspended sediment is removed through filtering, absorption, and gravity sedimentation.

Applicability

This practice is suitable as a sole BMP or in combination with additional BMP's for serving areas less than 5 acres. The vegetation in the vegetated filter strip shall be water and erosion resistant and shall have adequate stands of vegetation with minimal fertilization. The use of a vegetated filter strip is applicable on well drained or moderately well drained sites where the bedrock and water table are at least two feet below ground level. If the soil is moderately erodible in the drainage area, additional precautions will need to be taken to avoid excessive buildup of sediment in the grassed areas.

Grass Filter Strip Length (25' Min.) Shallow Ponding Limit Pervious Berm (Sand/Gravel Mix) Curb Parking Lot Slope Range Min.-6% Max Forest **Outlet Pipes** Buffer Water Quality Pea Gravel 12" Max. Treatment Volume Diaphragm

Figure 11-1 Vegetated Filter Strip

DCR, Virginia Stormwater Management Handbook, First Edition, 1999

<u>Advantages</u>

- Reduces particulate pollutants such as sediment, organic matter, and trace metals;
- Reduces water velocity promoting infiltration;
- May be implemented as part of landscaping requirements;
- Fits well in residential areas to provide open space for recreation, help maintain riparian zones, and reduce stream bank erosion;
- May help recharge groundwater where soil infiltration rates are adequate;
- Minimal implementation and maintenance costs in comparison to other BMPs.

<u>Disadvantages</u>

- Not designed to handle high velocity flows, so generally not applicable in large drainage areas with high impervious area development, or areas with steep slopes;
- Requires sheet flow to operate effectively and more concentrated channel flow may lead to erosion or gullies;
- Does not provide runoff storage or infiltration to significantly reduce peak discharges or volume of storm runoff; thus cannot be used to meet stormwater quantity requirements.

- Filter strips are only useful at controlling overland flow. A level spreader shall be utilized for concentrated flows. Where a level spreader is utilized, it shall have a rigid lip, either concrete or treated wood.
- All flow passing through the filter strip shall be from overland flow. Channel flow or a point source discharge is not acceptable.
- The minimum width of the filter strip is 25' and it should be as long as necessary to accommodate the overland runoff to be controlled.
- The acceptable longitudinal slope of any filter strip is 2% to 6%.

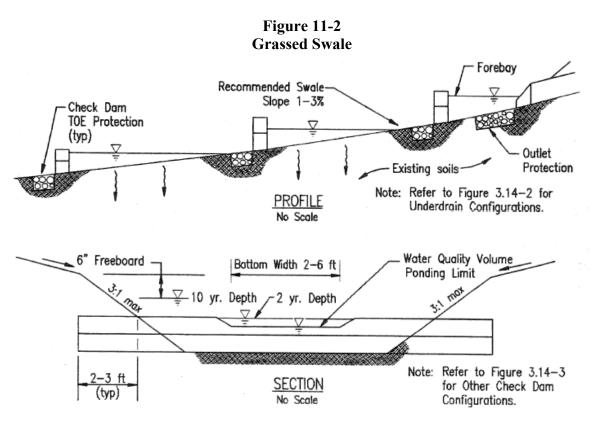
- Filter strips shall be used with soils having a minimum infiltration rate of 0.5 in/hour and soils shall be lightly used to prevent excessive compaction.
- The selection of vegetation shall be based on tolerance to water, growth rate, and stabilization capacity as well as maintenance considerations. Refer to the VA E&SC Handbook for specific recommendations.

11.5.3 Grassed Swale

Grassed swales with check-dams can be utilized to control peak discharges, filter particulate pollutants and increase infiltration. The concept requires check-dams to detain the initial runoff within the swales, while providing adequate hydraulic characteristics for larger design storms.

Applicability

This practice is most compatible for low runoff volume in low to moderate density residential (16% to 21% impervious area) development. Grassed swales do not function well with high volumes or velocities of stormwater. Site considerations such as soil type, topography, and the depth to the water table should also be considered in the evaluation of this BMP.

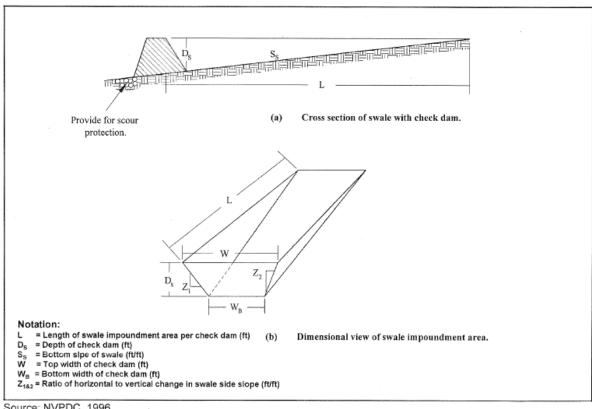


DCR, Virginia Stormwater Management Handbook, First Edition, 1999

Advantages

- May reduce runoff peak rates and increase opportunities for filtration, partially infiltrating runoff from small storm events if the underlying soil is not compacted or saturated;
- Reduces the use of costly development infrastructure, e.g., curb and gutter;
- Vegetative BMP is aesthetically pleasing;
- Low-slope grass swales can create wetland areas;
- Un-mowed systems not adjacent to roadways can provide valuable "wet meadow" habitat
- Less maintenance costs if dense, slow-growing vegetation is installed.

Figure 11-3 **Vegetated Swale With Check Dam**



Source: NVPDC, 1996.

<u>Disadvantages</u>

- If standing water is present, it may create a breeding ground for mosquitoes;
- Flows may concentrate as channel flow which may cause erosion at higher velocities;

- The topography of the site shall permit the design of a channel with a slope and cross sectional area sufficient to maintain an appropriate flow velocity. The flow velocity from the WQV through the grassed swale shall not exceed 1.5 feet per second. Velocity from a 2 year storm shall be less than 4 feet per second and the velocity from a 10 year storm shall be less than 7 feet per second;
- Grassed swales shall not be used on soils with infiltration rates less than 0.27 inches per hour.
- The seasonal high water table shall be no less than two feet below the bottom of the swale to ensure adequate opportunity for infiltration;
- Swale slope shall be between 2 and 4 percent. While DCR Figure 11-2 suggests a slope of 1-3%, Roanoke County minimum slope shall be 2%;
- Side-slopes of the swale shall not be steeper than 3:1;
- Bottom width of the swale shall be 6 feet minimum;
- Check dams shall be installed, sized, and spaced to store the water quality volume (WQV). Ponded water depth behind the check dams shall not exceed 18";
- Check dams shall be permanent and made of non-erodible materials;
- Overflow shall occur over the non-erodible material and not be allowed to scour around the area where the check dam meets the swale side slopes;
- Check dams must have water quality perforations designed to provide a detention time of 12 hours;

• Wire mesh and stone shall be placed in front of the water quality perforations.

11.5.4 Constructed Wetlands

Constructed wetlands are constructed systems that mimic the functions of natural wetlands and are designed to mitigate the impacts of urbanization on stormwater quality and quantity.

Applicability

Constructed wetlands provide an efficient method for removing a wide variety of pollutants, such as suspended solids, nutrients (nitrogen and phosphorus), heavy metals, toxic organic pollutants, and petroleum compounds. Properly designed wetlands can also be used to reduce pollution associated with high levels of fecal coliform contamination. These wetlands temporarily store stormwater runoff in shallow pools that support emergent and riparian vegetation. Wetlands can also effectively reduce peak runoff rates and stabilize flow to adjacent natural wetlands and streams. Constructed wetlands require maintenance to assure long-term pollutant removal.

Figure 11-4 Constructed Wetland



Constructed Stormwater Wetland. Note vegetation protected from waterfowl by netting system.

DCR, Virginia Stormwater Management Handbook, First Edition, 1999

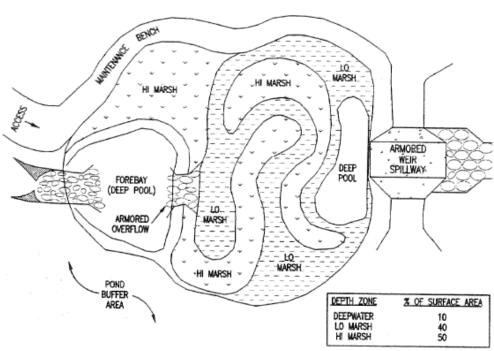


Figure 11-5 Constructed Wetland Plan

DCR, Virginia Stormwater Management Handbook, First Edition, 1999

Advantages

- Creates a shallow matrix of sediment, plants, water, and detritus that collectively removes multiple pollutants through a series of complementary physical, chemical, and biological processes;
- Provides good conditions for particle settling, sediment trapping, and reduction of suspended solids transport;
- Features relatively high efficiency in removing phosphorus, trace metals, and hydrocarbons that are adsorbed to the surfaces of suspended particles;
- Provides attenuation of peak flood flows;
- May be aesthetically pleasing if properly landscaped and maintained;
- Provides excellent habitat for wildlife and waterfowl;
- Relatively low maintenance when properly constructed and operated.

<u>Disadvantages</u>

- Occupies more land than other stormwater BMPs;
- When sited in watersheds that are too small to provide adequate hydration, wetlands tend to dry out frequently and function ineffectively;
- Can be colonized by invasive species that out-compete native wetlands plants and removal of invasive plants is difficult and labor intensive and may need to be done repeatedly;
- With certain industrial or commercial land uses in the drainage area, accumulated pollutants may eventually increase environmental risk to wildlife;
- If improperly designed, constructed wetlands may adversely impact existing wetland and forest areas in the region of the stormwater wetland by intercepting water that might otherwise reach the natural system;
- Overpopulation by waterfowl may increase the potential for bacterial contamination.

- Constructed wetlands shall be designed for a 10-year storm event;
- Side slopes shall be no steeper than 3H:1V;
- Embankments for constructed wetlands shall be constructed according to VA SWM Handbook;
- Sediment forebays shall be provided;
- Required permanent pool volume of wetland shall be two (2) times the water quality volume (WQV);
- Contributing watershed shall be a minimum of 10 acres and/or there should be an adequate base flow to support the hydrology;
- The surface area of the wetland shall be greater than or equal to 2% of the size of contributing watershed;

- Minimum length-to-width ratio of the pool shall be 1:1 in wet weather and 2:1 during dry weather;
- Deep pool depth zone design parameters:
 - \circ 1.5 6 feet depth;
 - o 10% of surface area; and
 - o 20% of treatment volume.
- Low marsh depth zone design parameters:
 - \circ 0.5 1.5 feet depth;
 - o 40% of surface area;
 - o A combined treatment volume in the low marsh and high marsh of 80%.
- High marsh design parameters:
 - \circ 0.0 0.5 feet depth;
 - o 50% of surface area; and
 - o A combined treatment volume in the low marsh and high marsh of 80%.
- Outlet structures shall be sized to pass the design storm with a maximum of two (2) feet of water ponded above the wetland pool;
- Design volume of constructed wetlands shall be such that they replace their water volume within 1 week and thus do not become problem areas for mosquito breeding.

11.5.5 Extended Detention and Enhanced Extended Detention Ponds

An extended detention (dry) pond is a basin that fills with stormwater during a rainfall event but will drain dry within a specified design period.

An enhanced extended detention pond is a basin with a shallow marsh in its bottom. This design has a higher efficiency of removing targeted pollutants because the shallow marsh provides additional pollutant removal through wetland plant uptake, absorption, physical filtration, and decomposition. By trapping the sediments, the shallow marsh also helps to reduce the re-suspension of settled pollutants.

Applicability

Without proper stormwater controls on site development projects, adverse downstream effects, including channel erosion and increased flooding can occur. In addition to stormwater quantity increases, stormwater can become polluted as it flows over construction and impervious surfaces picking up soil particles and pollutants.

Extended detention ponds are often used to control the quantity and quality of stormwater leaving an urban site. Designed to capture and slowly release stormwater runoff, dry ponds rely

almost exclusively on gravitational settling to remove pollutants. The pollutant removal effectiveness of the extended detention pond is based on the volume of runoff that can be stored and the release rate of the impounded water.

Maintenance ond Buffe Bench Vegetated Emergency Upper Stage Storage Spillway (Flood Control/Chann Erosion Control) Detention Pon Lo Marsh Warsh Нi Marsh Deep Sediment Forebay with Stabilized Overflow (Deep Pool) Hi-Morsh Sediment Lo Marsh Earthern Foreboy Embankment /Stabilized Overflow Multi-Stage Riser Structure Extended Detention Vehicle Control Structure Pond Buffer Depth Zone % of Surface Areas Deep Pool 20% 35% Lo Morsh \3_07-2a

Figure 11-6
Enhanced Extended Detention Basin

DCR, Virginia Stormwater Management Handbook, First Edition, 1999

For use of detention ponds for stormwater quantity management, see Chapter 9.

Advantages

• Effectively controls peak runoff discharge rates from both small and large drainage areas, thereby reducing potential for flooding and stream bank scour and erosion;

- Effective at removing suspended solids and particulate matter;
- Allows for recreational and other open-space uses between storm events;
- Presents less of a hazard to the public than wet basins due to the absence of a permanent pool of water.

Disadvantages

- Tends to develop a soggy bottom, hindering facility maintenance and the growth of effective vegetative cover;
- Unsightly if debris accumulates; however, the appearance can be improved by planting hardy wildflowers in the bottom;
- Unless adequately drained, can be perceived as a nuisance and eyesore to residents because of standing water;
- Clogged outlets can cause overflow during large rainfall events and result in erosion and flooding in downstream areas;
- Limited effectiveness in improving water quality by removing dissolved pollutants;
- Can be a safety hazard and fencing is typically considered unsightly;
- Requires large land areas and can be expensive to maintain.

- The 10-year post-development flow must be passed by the principal outlet structure and contained within the basin;
- The 100-year post-development flow must be passed using either the principal outlet structure, an emergency spillway, or a combination of both;
- A minimum of one foot of freeboard is required between the 100-year water surface elevation and the top of the basin;
- A minimum of six inches of freeboard is required between the 10-year water surface elevation and the emergency spillway elevation;

- Emergency spillways located in fill sections shall be lined with rip rap or concrete in accordance with the VA E&SC Handbook;
- Extended detention ponds shall be sized to hold the WQV requirements set forth in Table 11.1;
- Inlet and outlet structures shall be located and designed so that short circuiting does not occur;
- "Low flow" channels are not allowed in Extended Detention basins for this would allow the WQV to short-circuit the basin.
- Landscaping of the basin slopes that requires mulching, spraying, etc. shall be limited to the areas above the elevation of the top of the principal outlet structure elevation and must be done in such a manner so that the basin maintenance access will not be prohibited;
- Outlet structure, materials, joint connections, trash control, clogging, anti-vortex device, structural strength, and stability shall be addressed by the designer;
- Design of pond features shall be in accordance with the VA E&SC Handbook and the VA SWM Handbook;
- Sediment forebays shall be constructed at the influent points where stormwater enters
 a pond to trap incoming sediment prior to the basin itself. The sediment forebay shall
 be designed to be easily accessible by maintenance equipment for removal of
 sediment accumulations.
- All efforts will be made during basin design and construction to ensure that the basin functions as a "dry" basin.

11.5.6 Retention Ponds

A retention (wet) pond is a BMP that relies on settling as the primary removal method of removing pollutants from runoff. Retention ponds maintain a permanent water quality volume elevation.

Figure 11-7 Retention Basin



http://sjr.state.fl.us/programs/outreach/pubs/streamln/04summer/su04sln1.html

Applicability

Retention ponds, along with extended detention/shallow marsh basins are among the top BMPs in terms of providing water quality and quantity control benefits over a broad range of storm frequencies/sizes, drainage areas, and land use scenarios. Typically, retention ponds are restricted to drainage areas of 10 acres or more.

Retention ponds provide a large, deep permanent pool area, which is generally deep enough to discourage the establishment of wetland plants. The degree of pollutant removal achieved by a retention pond is a function of the size and design of the permanent pool. In theory, the incoming storm runoff displaces the "old water" out of the pond and is stored until the next storm. Suspended pollutants settle out from the water column to the pond sediments. The permanent pool acts as a barrier to re-suspension of deposited materials, improving removal performances over that achieved by extended detention.

Advantages

• Efficient removal method for suspended solids, heavy metals, and adsorbed pollutants and moderate to high removal of phosphorus, provided that the soil medium has low phosphorus content;

- Effectively controls peak runoff discharge rates, thereby reducing potential for flooding and stream bank scour and erosion;
- Very cost effective for regional or watershed-wide management facility applications.

Disadvantages

- Presents potential safety hazard to the public because of the presence of a permanent pool of water;
- Less cost effective for small drainage applications;
- Measures must be taken in high visibility areas to address the aesthetic issues related to a stagnant permanent pool;
- Clogged outlets can cause overflow during large rainfall events and result in erosion and flooding in downstream areas;
- Requires large land areas and can be expensive to maintain.

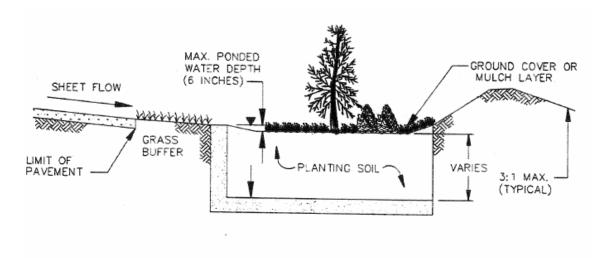
- A minimum contributing drainage area of 10 acres is required for a retention pond.
- The 10-year post-development flow must be passed by the principal outlet structure and contained within the basin;
- The 100-year post-development flow must be passed through the basin by either the principal outlet structure or an emergency spillway;
- A minimum of one foot of freeboard is required between the 100-year water surface elevation and the top of the basin;
- A minimum of six inches of freeboard is required between the 10-year water surface elevation and the emergency spillway elevation;
- Emergency spillways located in fill sections shall be lined with rip rap or concrete in accordance with the VA E&SC Handbook;

- Extended detention ponds shall be sized to hold the WQV requirements set forth in Table 11.1, matching the removal efficiency used in the water quality calculations;
- Inlet and outlet structures shall be located and designed so that short circuiting does not occur;
- Landscaping of the basin slopes that requires mulching, spraying, etc. shall be limited to the areas above the elevation of the top of the principal outlet structure elevation and must be done in such a manner so that the basin maintenance access will not be prohibited;
- Outlet structure, materials, joint connections, trash control, clogging, anti-vortex device, structural strength, and stability shall be addressed by the design;
- Design of pond features shall be in accordance with the VA E&SC Handbook and the VA SWM Handbook;
- Sediment forebays shall be constructed at the influent points where stormwater enters a pond to trap incoming sediment prior to the basin itself. The sediment forebay shall be designed to be easily accessible by maintenance equipment for removal of sediment accumulations;
- Retention ponds located in or adjacent to residential areas must include a 10' wide aquatic bench.

11.5.7 Bioretention Filter

Bioretention filters are a method to manage stormwater runoff using native plants and soil conditioning in addition to pond-type settling.

Figure 11-8 Bioretention Basin



DCR, Virginia Stormwater Management Handbook, First Edition, 1999

Applicability

Bioretention filters are conceived to capture sheet flow from impervious surfaces and are suitable for a wide range of projects from single-family residential to fairly high density commercial.

<u>Advantages</u>

- Efficient removal method for suspended solids, heavy metals, and adsorbed pollutants and moderate to high removal of phosphorus, provided that the soil medium has low phosphorus content. Certain configurations allow for moderate-high removal of nitrogen;
- Effective means of reducing peak runoff rates for relatively frequent storms, reducing runoff volumes and recharging groundwater by infiltrating runoff;
- Flexible adaptation to urban retrofits;
- Successful use in small areas and, as distributed control measures, in large drainage areas or as part of low impact development;
- Natural integration into landscaping for habitat enhancement.

Disadvantages

• In residential applications, homeowners need training to maintain the plant material and mulch layer, and provide general cleaning;

- Depending upon design, they may not be effective at removing nitrate;
- Surface soil layer may clog over time, requiring maintenance to restore;
- Frequent trash removal may be required, especially in high traffic areas;
- Vigilance in protecting the bioretention area during construction is essential.

- Six major design components shall be incorporated into a bioretention filter: grass buffer strip, ponding area, planting soil, sand bed, organic layer, plant material, and underdrain system;
- The bioretention area shall be sized to meet the following standards:
 - o Minimum width of 15 feet;
 - o Minimum length shall be 40 feet. For widths equal to or greater than 20 feet, the length of the bioretention area shall be at least twice the width;
 - o The ponded area shall have a maximum depth of 12 inches;
 - o The planting soil shall have a minimum depth of 4 feet;
 - o The sand bed shall have a depth of 1 foot;
 - o The minimum width of the buffer strip shall be 10 feet.
- A one foot wide sand wall shall extend around all sides of the bioretention area that receives surface runoff;
- The design shall incorporate a bypass to take runoff around the BMP once the ponding area has filled to capacity;
- Filter fabric shall be placed between the sand and planting soil layers;
- Trees and shrubs shall be provided at a rate of 1,000 total stems per acre of BMP surface area. The total number should be distributed such that for every tree there are three shrubs;
- The water table must be at least two feet below the bottom of the BMP:
- The twelve inch ponding area over the surface area of the BMP must hold the water quality volume (WQV);

- The planting material shall meet the following requirements:
 - The plant material shall be chosen and placed to replicate a forest community structure. The layout should follow two basic guidelines. First, woody plant material should not be placed within the immediate areas of where flow will be entering the BMP. Secondly, trees shall be planted primarily on the perimeter of the bioretention area to maximize shading and sheltering;
 - At installation, trees should be 2.5 inches in caliper, and shrubs 3 to 4 feet in height or 18 to 24 inches in spread. Ground cover may be as seed or, preferably, plugs;
 - A minimum of 3 species of trees and three species of shrubs should be selected to insure diversity;
 - A planting plan shall be submitted and approved with the construction plans and as part of the landscape plan;
- Perforated underdrains shall be provided beneath the bottom sand layer. The underdrains shall be a minimum of 4 inches in diameter. In order to provide 2 inches of cover, they shall be placed in 6 inches of stone. The underdrains shall be connected to a positive outfall;
- The planting soil used in the bioretention area must have a composition of at least 10% to 25% clay and shall be of a sandy loam or loamy sand texture. Loamy soils may be used if the composition consists of 35% sand;
- The planting soil shall be of uniform composition, free of stones, stumps, roots or similar objects larger than one inch, brush, or any other material or substance which may be harmful to plant growth, or a hindrance to planting or maintenance operations, and shall be free of plants or plant parts of Bermuda grass, Quack grass, Johnson grass, Mugwort, Nutsedge, Poison Ivy, and Canadian Thistle;
- The planting soil must meet the following criteria:

 $\begin{array}{lll} pH \ range & 5.5 - 6.5 \\ Organic \ matter & 1.5 - 3.0\% \\ Magnesium - Mg & 35 \ lbs./acre \\ Phosphorus - <math>P_2O_5$ & 100 lbs./acre \\ Potassium - K_2O & 85 lbs./acre

Soluble salts not to exceed 500 ppm

11.5.8 Infiltration Devices

Infiltration devices include dry wells, trenches, or basins that fill with stormwater runoff and allow the water to exfiltrate by infiltrating into the soil.

Applicability

"Infiltration," in the context of BMPs, refers to the process of stormwater infiltrating into the soil. A number of infiltration devices with differing designs have been used in various locations throughout the country. This section discusses three types: infiltration trenches, infiltration basins, and dry wells.

Diservation Well

20' Grass Filter
Slope < 5%

Replaceable Filter Fabric

Failure Plane

Filter Fabric

Keyed In At Top

Aggregate

Figure 11-8
Infiltration Trench

DCR, Virginia Stormwater Management Handbook, First Edition, 1999

Infiltration devices enhance percolation to groundwater by:

• Directing surface runoff to locations where it can come into contact with pervious underlying soils;

• Capturing runoff until it can infiltrate into the underlying soil.

Infiltration trenches are filled with large crushed stone or other media to create storage for the stormwater in the voids between the media. Other options use precast concrete vaults with open bottoms to provide a large storage volume to hold stormwater for infiltration into the soil. Infiltration trenches are usually used to manage the runoff from parking lots and buildings.

Infiltration basins are normally dry basins, much like extended dry detention basins, with the exception that the stormwater is allowed to exfiltrate.

Dry wells are similar to infiltration trenches but are sufficiently smaller to be considered as a separate BMP. Dry wells are most useful for receiving the runoff from roofs of buildings and allowing it to infiltrate into the soil.

Infiltration devices reduce runoff volume, recharge groundwater, and have high removal efficiencies for sediment and for pollutants adsorbed onto sediment particles.

<u>Advantages</u>

- Reduces frequency of downstream flooding by increasing the quantity of water entering the soil;
- Maintains shallow groundwater levels, which may support dry-weather flows in streams;
- Particulate pollutant removal efficiencies are generally as good as other BMPs;
- Very economical for small drainage areas (<10,000 ft³ storage volume).

Disadvantages

- May fail relatively quickly compared to other types of BMPs due to improper maintenance or excess sediment trapped;
- Tend to clog very easily with sediment, so a pretreatment BMP shall be used to remove coarse particulate pollutants;
- Use is restricted to areas with permeable soils, deep water tables, deep bedrock, and stable areas where stormwater contains little sediment or can be pretreated to reduce the sediment load;
- Requires significant maintenance to enhance longevity and maintain performance;

- May cause undesirable groundwater seepage into basements and foundations if not properly sited;
- Infiltration of stormwater runoff from hotspots may contribute to the contamination groundwater or soils.

Site Limitations

The locations of infiltration devices are limited as follows:

- From the invert of the infiltration device to a depth of 3 feet below the invert:
 - o There shall be no impermeable strata or clay lenses to impact infiltration.
 - o Bedrock shall not be present.
 - o Groundwater shall not be present.
 - O Soils shall have an infiltration rate greater than 0.52 inches per hour and less than 8.27 inches per hour.
- Infiltration devices shall not be located on fill material.
- Infiltration devices shall not be located on soils with 30-percent or greater clay content as they are structurally unstable and subject to frost heave.
- Infiltration devices shall not be placed on slopes greater than 20 percent.
- Infiltration devices shall not be located within 20 feet of a structure when it is down gradient from the structure or within 100 feet when it is up gradient of the structure.
- Infiltration devices shall not be located in areas of karst geology. The Roanoke valley has extensive areas of karst geology.
- Infiltration devices shall not be used to infiltrate stormwater runoff from hotspots or to infiltrate stormwater runoff that includes a contaminated non-stormwater component.
- Infiltration devices shall not be used where stormwater is being managed in a designated groundwater recharge area.
- Infiltration devices shall not be located within 100 feet of a drinking water well.
- Infiltration devices shall not be located within 20 feet of a wastewater septic tank or drain field.

Infiltration Trench Design Criteria

- Infiltration trenches shall be sited in accordance with the site limitations;
- The area draining to an infiltration trench shall be less than 5 acres;
- Design shall be based on soil boring results. See Chapter 13 for soil boring and geotechnical study requirements;
- All infiltration trenches shall be fitted with an observation well, consisting of a 4" to 6" perforated PVC pipe with a tamper resistant access cap. One well shall be provided for each 300 feet of infiltration trench with a minimum of one well per individual trench;
- Infiltration trenches shall be designed to infiltrate the design volume between 6 and 48 hours after the storm event, using a design infiltration rate that is half the infiltration rate determined from the soil analysis;
- Aggregate used in the infiltration trench shall be 1 to 3 inch diameter clean washed stone, VDOT type 1 or 2, with a 40% void ratio;
- All stormwater runoff shall be filtered of coarse sediment, oil and grease before it enters the infiltration trench. A minimum 20 foot wide grass buffer strip or other pretreatment device shall be used;
- The infiltration trench shall include measures for handling overflows and the design shall be capable of passing at least a 5-year storm without stormwater backup ponding on adjacent property.

Dry Well Design Criteria

The design of the dry well shall meet the requirements for infiltration trench design except as noted below:

- Roof top drainage shall be filtered by screens placed at the top of the roof down drains to prevent leaves and other debris from clogging the drywell;
- Dry wells shall be designed to capture 0.5" of runoff from the roof top area. All additional runoff shall be handled by an overflow pipe. All downstream drainage facilities shall be designed to accommodate 100% of roof top drainage in areas that employ dry wells, assuming no infiltration occurs.

Infiltration Basin Design Criteria

- Infiltration basins shall be sited in accordance with the site limitations;
- The area draining to an infiltration trench shall be less than 50 acres;
- Design shall be based on soil boring results. See Chapter 13 for soil boring and geotechnical study requirements;
- Infiltration basin side slopes shall be 3H:1V or flatter;
- To receive the indicated pollutant removal efficiency, the infiltration basin shall be designed to meet the WQV requirements set by Table 11.1 for Infiltration I or Infiltration II;
- Infiltration basins shall be designed to infiltrate the design volume between 6 and 48 hours after the storm event, using a design rate that is half the infiltration rate determined from the soils analysis;
- All stormwater runoff shall be filtered of coarse sediment, oil and grease before it enters the infiltration basin;
- The infiltration basin shall be include measures for handling overflow drainage and the design shall be capable of passing at least a 5-year storm without stormwater ponding on adjacent property;
- A dense growth of grass shall be established on the bottom and sides of the infiltration basin. Tall fescues, Bermuda grass, or other approved water tolerant grasses shall be used in accordance with the VA Erosion and Sediment Control Handbook, Current Edition, as amended;

11.5.9 Sand Filter

A sand filter is a device used to remove pollutants by filtering runoff through a bed of sand.

Figure 11-9 Sand Filter



Photograph of a Sand Filter. City of Portland. Stormwater Management Handbook Revision #2. 2002

Applicability

Sand filters use physical straining to remove suspended solids and particulate nutrients. There are two types of sand filter systems; systems that provide partial sedimentation pretreatment and those that provide full sedimentation pretreatment. Full sedimentation systems involve the use of a basin that detains the water quality volume for 12 hours immediately up gradient from the sand filter. The sizing criteria vary depending on whether full or partial sedimentation is provided.

Advantages

- Highly effective at filtering solids from the stormwater flow;
- Filters can handle stormwater flows from moderate to large areas;
- Larger sand filters can provide some attenuation of runoff peak flows, particularly when the design storm is less than 10-year frequency;
- Underground closed filters are useful where space is limited;
- Perimeter closed filters useful for small sites with flat terrain or high water table.

<u>Disadvantages</u>

- Trash screens or grated inlets shall be integrated in all designs so materials that can cause premature failures are kept out of the filter chambers. Frequent cleaning of these screens and inlets may be required;
- Anoxic conditions may develop in the sand filter causing increases in phosphorus levels;
- Not totally effective in controlling stormwater quantity, especially for larger peak discharges;
- Large sand filters without grass cover may not be attractive in residential areas;
- Trash accumulation on the surface of sand filters can be unattractive.

- The sand filtration chamber shall contain a minimum 18 inch layer of sand over a minimum 6 inch layer of stone;
- Filter fabric shall be placed between the sand and stone layers;
- When the sand filter length exceeds 20 feet, a 4 inch diameter perforated under drain shall be placed within the stone layer. Two inches of stone cover shall be provided over the under drain. Under drains shall be wrapped in filter fabric and spaced 2 feet on center;
- An internal weir, sized to pass the 10-yr post-developed flow, shall be provided between the sedimentation chamber and the clear well;
- The sand filter bottom shall be sloped towards the clear well at a minimum slope of 1%;
- When the filter will be subjected to traffic loads or significant earth loads, the concrete vault shall be designed accordingly;
- Filter fabric and a 2 inch thick layer of rock shall be placed on top of the sand;
- Weirs located in the wall between the sedimentation chamber and the sand filtration chamber shall be 3" or 4" in diameter and spread one foot on center;
- An access for inspection and maintenance activities shall be provided;
- Trash racks shall be installed over the curb openings into the sand filter;

• Observation wells (with threaded caps) are required in the sand filter chamber and shall be located at the access manhole on the upper end of the structure.

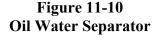
11.5.10 Oil Water Separator

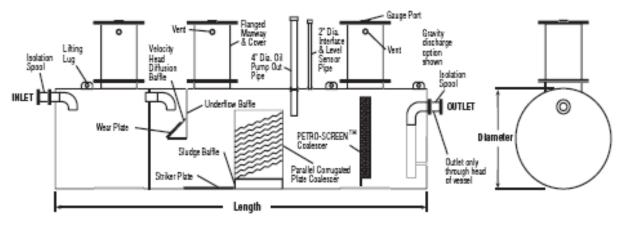
An oil water separator may be used as a pretreatment system when a significant stormwater component is expected to be hydrocarbon fuels, oils, greases, or other lubricants. An oil water separator is designed to separate oil from stormwater by trapping the oil which floats on the surface. Oil water separators are not designed to remove sediment, phosphorus, or other pollutants from the stormwater. Thus, no pollutant removal efficiency credit has been established for oil water separators as a BMP when utilizing the Simple Method to determine removal rates under the performance-based or technology-based criteria.

Oil water separators are generally used on small, urban lots where hydrocarbons could reasonably be expected to be on the ground, including parking lots, gas stations, lube shops, and other areas with substantial vehicular traffic or parking.

Applicability

The purpose of an oil water separator is to remove fuels, oils, and lubricants in stormwater and washwater that would otherwise be flushed into the storm sewer system or receiving channels. An oil water separator is most likely used as a pretreatment structure before a standard BMP.





Oil/Water Separator from Highland Tank and Mfg. Co.

Advantages

- Effectively prevents hydrocarbon fuels, oils, greases, and lubricants from entering the stormwater system;
- Very low maintenance requirements;
- Oil water separators are most often located underground minimizing its surface footprint and aesthetic impacts;
- Ideal for small (<1 acre), highly impervious areas, such as gas stations, loading areas, maintenance areas, or parking lots.

Disadvantages

- Repairs of oil water separators may be expensive;
- Periodic monitoring and emptying of the oil water separator is required;
- Waste product must be disposed of as a oil-based waste;
- Oil water separator does not handle stormwater quantity, nor removal of other pollutants such as sediment or phosphorus;
- Construction costs for larger sites could become prohibitive. In these cases it would be best to divert non-contaminated stormwater away from the oil water separator;

- Oil water separators shall be designed according to the American Petroleum Institute (API) standards;
- Design calculations, drawings, and details shall be submitted with the stormwater management plan;
- If a pre-manufactured oil water separator is planned, the following information shall be submitted with the stormwater management plan:
 - A statement from the manufacturer indicating that the oil water separator is designed per the API standards;
 - o A detail drawing of the oil water separator;
- A trench drain system shall be installed to divert the wastewater flow to the oil water separator. The trench drain must fully encompass the area that produces wastewater;

• The site shall be graded so the runoff from the surrounding area, that does not contain hydrocarbons, will not enter the trench drain or the oil water separator.

11.5.11 Permeable Pavement

Permeable pavement is an alternative to conventional concrete and asphalt paving materials that allows for rapid infiltration of stormwater. Stormwater infiltrates into a porous paving material that provides temporary storage until the water infiltrates into underlying permeable soils or through an underground drain system.

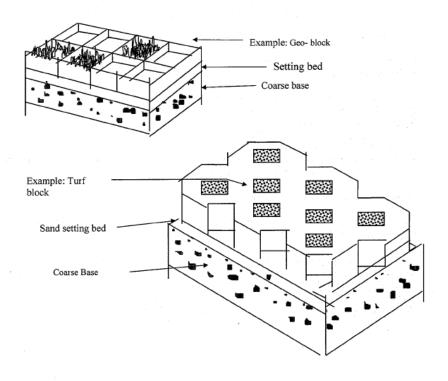
Applicability

Traditional paved surfaces, such as asphalt and concrete, do not allow water to infiltrate and convert almost all rainfall into runoff. If designed and implemented correctly, permeable pavement systems allow at least a portion of stormwater to infiltrate, thus reducing peak runoff volumes and flows. Permeable paving materials include, but are not necessarily limited to, porous concrete, permeable interlocking concrete pavers, concrete grid pavers, and porous asphalt.

Permeable pavers are allowed in low volume drive areas and low use parking areas. Coordinate with the County prior to using permeable pavers to ensure that the proposed location is acceptable for the County to grant BMP credit.

Permeable asphalt and porous concrete shall not normally be used as a BMP due to the special care that is required during construction for the pavement to function properly and the maintenance (power washing and vacuuming) that is required.

Figure 11-11 Permeable Pavers



Detail of Permeable Pavers, City of Portland, Stormwater Management Manual Revision #2, 2002

Permeable asphalt and porous concrete will only be allowed when the applicant provides adequate documentation to show that the mix plant and the contractor that will install the permeable asphalt or porous concrete are experienced and skilled with the product and adequate third party inspection under the direction of a professional engineer that is experienced with permeable asphalt and porous concrete will be provided full-time during the installation. In addition, the maintenance agreement must identify how necessary maintenance will be performed.

Advantages

- Turns completely impervious surfaces into partially impervious surfaces reducing the stormwater runoff rate and volume;
- Reduces loads of some pollutants in surface runoff by reducing the volume of stormwater leaving a site;
- Potential component of Low-Impact Development (LID) site designs.

Disadvantages

- Permeable asphalt and porous concrete require a high degree of quality control by the mix plant and the installing contractor that are experienced in these materials and installations;
- Potential for clogging of porous media by sediment, which would lead to reduced effectiveness;
- High maintenance requirements to prevent porous media from clogging;
- Higher cost than conventional pavement;
- Not applicable for high-traffic areas or for use by heavy traffic vehicles;
- Permeable pavement installation must have a slope less than 0.5%;
- Rehabilitation is costly. Often complete replacement is required if failure occurs.

Design Criteria

- Typically, the structural requirements of permeable pavement systems will provide sufficient temporary storage for permeable pavement to store and infiltrate stormwater. Permeable pavement does not receive a pollutant removal credit, instead a portion of the permeable pavement is calculated as non impervious area when using the Simple Method. At a minimum, permeable pavement must have at least 4 inches of washed stone base to receive water quality credit as 40% managed grass area/60% impervious area, and 6 inches of washed stone base to receive credit as 60% managed grass area/40% impervious area;
- A washed aggregate, #57 stone base must be used;
- Permeable pavements that rely on an underdrain system to discharge stormwater shall draw down the stored water within the permeable pavement base from the 1-year, 24-hour rain event in no less than 48 hours:
- Permeable pavements shall have a low traffic volume, less than 40 vehicles per day;
- The seasonally high water table shall be at least 2 feet below the base of the permeable pavement or gravel storage layer.

11.5.13 Manufactured BMP Systems

A manufactured BMP system is a structural measure which is specifically designed and sized by a manufacturer to intercept stormwater runoff and prevent the transfer of pollutants downstream.

DCR has in the past approved several manufactured BMP systems for use in meeting stormwater quality requirements. Information regarding DCR-approved manufactured BMP systems is included in the VA SWM Handbook. Additional manufactured systems may be found on DCRs website as new technologies are approved and added. DCR acknowledges that additional manufactured BMP systems are and may become available which are not presented in the VA SWM Handbook and DCR acceptance does not constitute endorsement of any one system.

Applicability

Manufactured BMP systems may be suitable for providing stormwater quality enhancement where other structural BMPs are not feasible due to limited land space, flows, or velocities. Applicability is likely to vary based on the manufactured BMP system.

Pollutant removal efficiencies are presented in the VA SWM Handbook are based on currently available studies and may vary due to storm size, pollutant concentrations, and rainfall intensity. These may be subject to change as better data becomes available.

Advantages

• Small size of many manufactured BMPs will provide efficient use of land. Many manufactured BMPs may be retrofitted beneath improved areas.

Disadvantages

- High maintenance requirements and if placed beneath improved areas, often difficult access for maintenance.
- Underground manufactured BMPs have limited outfalls for discharging releases. Typically these discharge into a storm drain system rather than an open channel.

Design Criteria

- Design criteria shall be based on DCRs approved design criteria for an approved manufactured BMP system.
- Where criteria is not designated by DCR, design criteria shall be obtained from the manufacturer. All designs shall be reviewed by the manufacturer to ensure that the system is properly designed and sized.

• All acceptable manufactured BMP systems shall be capable of being inspected from the ground surface without the need for confined space entry.

Maintenance

Maintenance of manufactured BMP system is required on a regular basis to maximize their effectiveness. The specific maintenance requirements and frequency of maintenance for each individual manufactured BMP system shall be prepared by the manufacturer and be included as a part of the approved Stormwater Management Plan maintenance agreement.

11-38

APPENDIX 11A

AIDS FOR SIMPLE METHOD CALCULATIONS

FROM VIRGINIA STORMWATER MANAGEMENT HANDBOOK CHAPTER 5 AND APPENDIX 5D

Performance-Based Water Quality Calculations Worksheet 1 (Page 1 through 3)

Performance-Based Water Quality Calculations Worksheet 2: Situation 2 (Page 1 through 4)

Performance-Based Water Quality Calculations Worksheet 3: Situation 3 (Page 1 through 5)

Performance-Based Water Quality Calculations Worksheet 4: Situation 4 (Page 1 through 6)

Urban Land Use Impervious Cover and Annual Pollutant Load

Worksheet 1

Page 1 of 3

STEP 1	Determine the applicable area (A) and the post-developed impervious cover (I_{post}).
	Applicable area (A)* = acres
	Post-development impervious cover:
	structures =acres
	parking lot =acres
	roadway =acres other:
	acres
	acres
	Total =acres
$I_{post} =$	(total post-development impervious cover ÷ A) × 100 =
*	The area subject to the criteria may vary from locality to locality. Therefore, consult the locality for proper determination of this value.
STEP 2	Determine the average land cover condition $(I_{watershed})$ or the existing impervious cover $(I_{existing})$.
If the	ge land cover condition $(I_{watershed})$: locality has determined land cover conditions for individual watersheds within its ection, use the watershed specific value determined by the locality as $I_{watershed}$.
•	$I_{\text{watershed}} = \underline{\hspace{1cm}}_{0}$
Other	wise, use the Chesapeake Bay default value:
	$I_{\text{watershed}} = 16\%$

Worksheet 1

Page 2 of 3

Existing impervious cover (I_{existing}):

Determine the existing impervious cover of the development site if present.

Existing impervious cover:

	structures	=	_acres
	parking lot	=	_acre
other:	roadway	=	_acres
-		=	_acres
		=	_acres
	Total	=	acres

* The area should be the same as used in STEP 1.

STEP 3 Determine the appropriate development situation.

The site information determined in STEP 1 and STEP 2 provide enough information to determine the appropriate development situation under which the performance criteria will apply. Check () the appropriate development situation as follows:

Situation 1: This consists of land development where the existing percent impervious cover $(I_{existing})$ is less than or equal to the average land cover condition $(I_{watershed})$ and the proposed improvements will create a total percent impervious cover (I_{post}) which is less than or equal to the average land cover condition $(I_{watershed})$.

 I_{post} $\frac{\%}{} \le I_{watershed}$ $\frac{\%}{}$

Worksheet 1

Page 3 of 3

Situation 2:	This consists of land development where the existing percent impervious cover $(I_{existing})$ is less than or equal to the average land cover condition $(I_{watershed})$ and the proposed improvements will create a total percent impervious cover (I_{post}) which is greater than the average land cover condition $(I_{watershed})$.								
	$I_{\text{existing}} = \frac{0/0}{2} \le I_{\text{watershed}} = \frac{0/0}{2}$; and								
	I_{post}								
Situation 3:	This consists of land development where the existing percent impervious cover $(I_{existing})$ is greater than the average land cover condition $(I_{watershed})$.								
	$I_{\text{existing}} = \frac{\%}{2} > I_{\text{watershed}} = \frac{\%}{2}$								
Situation 4:	This consists of land development where the existing percent impervious cover $(I_{existing})$ is served by an existing stormwater management BMP(s) that addresses water quality.								

If the proposed development meets the criteria for development Situation 1, than the low density development is considered to be the BMP and no pollutant removal is required. The calculation procedure for Situation 1 stops here. If the proposed development meets the criteria for development Situations 2, 3, or 4, then proceed to <u>STEP 4</u> on the appropriate worksheet.

Page 1 of 4

Summary of Situation 2 criteria: from calculation procedure STEP 1 thru STEP 3, Worksheet 1:

Applicable area $(A)^* =$ acres

 $I_{\text{watershed}} = \frac{\%}{}$ or $I_{\text{watershed}} = 16\%$

 $I_{\text{existing}} = \text{(total existing impervious cover} \div A^*) \times 100 = \underline{\qquad \%}$

 $I_{\text{existing}} = \frac{0}{0} \le I_{\text{watershed}} = \frac{0}{0}$; and

STEP 4 Determine the relative pre-development pollutant load (L_{pre}).

 $\mathbf{L}_{\text{pre(watershed)}} = [0.05 + (0.009 \times I_{\text{watershed}})] \times A \times 2.28 \quad \text{(Equation 5-16)}$

where: $L_{pre(watershed)}$ = relative pre-development total phosphorous load (pounds per year) $I_{watershed}$ = average land cover condition for specific watershed or locality **or**

the Chesapeake Bay default value of 16% (percent expressed in

whole numbers)
A = applicable area (acres)

 $\mathbf{L}_{\text{pre(watershed)}} = [0.05 + (0.009 \times ____)] \times ___ \times 2.28$

= _____ pounds per year

Page 2 of 4

STEP 5 Determine the relative post-development pollutant load (L_{post}).

$$\begin{aligned} \mathbf{L_{post}} &= [0.05 + (0.009 \times \mathbf{I_{post}})] \times \mathbf{A} \times 2.28 & \textbf{(Equation 5-21)} \\ \text{where:} & \mathbf{L_{post}} &= \text{relative post-development total phosphorous load (pounds per year)} \\ \mathbf{I_{post}} &= \text{post-development percent impervious cover (percent expressed in whole numbers)} \\ \mathbf{A} &= \text{applicable area (acres)} \\ \mathbf{L_{post}} &= [0.05 + (0.009 \times \underline{\hspace{1cm}})] \times \underline{\hspace{1cm}} \times 2.28 \\ &= \underline{\hspace{1cm}} \text{pounds per year} \end{aligned}$$

STEP 6 Determine the relative pollutant removal requirement (RR).

$$\mathbf{RR} = \mathbf{L}_{post} - \mathbf{L}_{pre(watershed)}$$

$$\mathbf{RR} = \underline{\qquad} - \underline{\qquad}$$

$$= \underline{\qquad} pounds per year$$

STEP 7 Identify best management practice (BMP) for the site.

1. Determine the required pollutant removal efficiency for the site:

Page 3 of 4

	2.	Select	BMP(s) from	Table :	5-15	and	locate	on	the	sit	te:
--	----	--------	-------	--------	---------	------	-----	--------	----	-----	-----	-----

BMP 1:_______
BMP 2:______

3. Determine the pollutant load entering the proposed BMP(s):

$$L_{BMP} = [0.05 + (0.009 \times I_{BMP})] \times A \times 2.28$$
 (Equation 5-23)

where: L_{BMP} = relative post-development total phosphorous load entering proposed BMP (pounds per year)

I_{BMP} = post-development percent impervious cover of BMP drainage area (percent expressed in whole numbers)

A = drainage area of proposed BMP (acres)

$$\mathbf{L}_{\mathbf{BMP1}} = [0.05 + (0.009 \times ___)] \times ___ \times 2.28$$

= _____ pounds per year

$$L_{BMP2} = [0.05 + (0.009 \times ____)] \times ___ \times 2.28$$

= _____ pounds per year

$$L_{BMP3} = [0.05 + (0.009 \times ___)] \times __ \times 2.28$$

= _____ pounds per year

Page 4 of 4

4. Calculate the pollutant load removed by the proposed BMP(s):

 $L_{removed} = Eff_{BMP} \times L_{BMP}$ (Equation 5-24)

where: $L_{removed}$ = Post-development pollutant load removed by proposed BMP (pounds per year)

Eff_{BMP} = pollutant removal efficiency of BMP (expressed in decimal form)

L_{BMP} = relative post-development total phosphorous load entering proposed BMP (pounds per year)

L_{removed/BMP1} = _____ × ____ = ____ pounds per year

 $L_{removed/BMP2} =$ pounds per year

 $L_{removed/BMP3} =$ _____ × ___ = ____ pounds per year

5. Calculate the total pollutant load removed by the BMP(s):

 $L_{removed/total} = L_{removed/BMP1} + L_{removed/BMP2} + L_{removed/BMP3} + \dots$ (Equation 5-25)

where: $L_{removed/total} = L_{removed/BMP1} = total pollutant load removed by proposed BMPs pollutant load removed by proposed BMP No. 1 pollutant load removed by proposed BMP No. 2 <math>L_{removed/BMP2} = L_{removed/BMP3} = total pollutant load removed by proposed BMP No. 3$

 $\mathbf{L}_{removed/total} = \underline{\hspace{1cm}} + \underline{\hspace{1cm}} + \underline{\hspace{1cm}} + \ldots$ $= \underline{\hspace{1cm}} pounds per year$

6. Verify compliance:

L_{removed/total} ≥ RR

Page 1 of 5

Summary of Situation 3 criteria: from calculation procedure STEP 1 thru STEP 3, Worksheet 1:

Applicable area $(A)^* =$ acres

$$I_{\text{watershed}} = 0$$
 or $I_{\text{watershed}} = 16\%$

$$I_{\text{existing}} = (\text{total existing impervious cover} \div A^*) \times 100 = _________$$

$$I_{\text{existing}} = \frac{\%}{\%} > I_{\text{watershed}} = \frac{\%}{\%}$$

STEP 4 Determine the relative pre-development pollutant load (L_{pre}) .

1. Pre-development pollutant load based on the existing impervious cover:

$$\mathbf{L}_{\text{pre(existing)}} = [0.05 + (0.009 \times I_{\text{existing}})] \times A \times 2.28 \quad \text{(Equation 5-17)}$$

where:

 $L_{\text{pre(existing)}}$ = relative pre-development total phosphorous load (pounds per year) = existing site impervious cover (percent expressed in whole numbers)

A = applicable area (acres)

$$L_{\text{pre(existing)}} = [0.05 + (0.009 \times \underline{})] \times \underline{} \times 2.28$$

$$= \underline{} \text{pounds per year}$$

Page 2 of 5

2. Pre-development pollutant load based on the average land cover condition:

$$\mathbf{L}_{\text{pre(watershed)}} = [0.05 + (0.009 \times I_{\text{watershed}})] \times \mathbf{A} \times 2.28 \quad \text{(Equation 5-16)}$$

where:

L_{pre(watershed)} = relative pre-development total phosphorous load (pounds per year)

= average land cover condition for specific watershed or locality or
the Chesapeake Bay default value of 16% (percent expressed in
whole numbers)

A = applicable area (acres)

$$\mathbf{L}_{\text{pre(watershed)}} = [0.05 + (0.009 \times \underline{})] \times \underline{} \times 2.28$$

$$= \underline{} \text{pounds per year}$$

STEP 5 Determine the relative post-development pollutant load (L_{post}).

$$L_{post} = [0.05 + (0.009 \times I_{post})] \times A \times 2.28$$
 (Equation 5-21)

where:

L_{post} = relative post-development total phosphorous load (pounds per vear)

 I_{post} = post-development percent impervious cover (percent expressed in

whole numbers)
A = applicable area (acres)

$$\mathbf{L}_{post} = [0.05 + (0.009 \times \underline{})] \times \underline{} \times 2.28$$

$$= \underline{} \quad pounds \text{ per year}$$

STEP 6 Determine the relative pollutant removal requirement (RR).

RR =
$$L_{post}$$
 - $(0.9 \times L_{pre(existing)})$
= _____ - $(0.9 \times ____)$ = ____ pounds per year

$$\mathbf{RR} = \mathbf{L}_{post} - \mathbf{L}_{pre(watershed)}$$

$$= \underline{\hspace{1cm}} - \underline{\hspace{1cm}} = \underline{\hspace{1cm}} pounds per year$$

 \mathbf{or}

Page 3 of 5

The pollutant removal requirement (RR) for Situation 3 is the lesser of the two values calculated above:

RR = _____ pounds per year

STEP 7 Identify best management practice (BMP) for the site.

1. Determine the required pollutant removal efficiency for the site:

$$\mathbf{EFF} = (RR \div L_{post}) \times 100$$

(Equation 5-22)

where:

EFF = required pollutant removal efficiency (percent expressed in whole numbers)

RR = pollutant removal requirement (pounds per year)

L_{post} = relative post-development total phosphorous load (pounds per

2. Select BMP(s) from Table 5-15 and locate on the site:

BMP 1:____

BMP 2:____

BMP 3:_____

Page 4 of 5

3. Determine the pollutant load entering the proposed BMP(s):

$$L_{BMP} = [0.05 + (0.009 \times I_{BMP})] \times A \times 2.28$$
 (Equation 5-23)

where:

L_{BMP} = relative post-development total phosphorous load entering proposed BMP (pounds per year)

I_{BMP} = post-development percent impervious cover of BMP drainage area (percent expressed in whole numbers)

A = drainage area of proposed BMP (acres)

$$L_{BMP1} = [0.05 + (0.009 \times ____)] \times ___ \times 2.28$$

= _____ pounds per year

$$L_{BMP2} = [0.05 + (0.009 \times ___)] \times ___ \times 2.28$$

= _____ pounds per year

$$\mathbf{L}_{BMP3} = [0.05 + (0.009 \times ____)] \times ___ \times 2.28$$

= _____ pounds per year

4. Calculate the pollutant load removed by the proposed BMP(s):

$$L_{removed} = Eff_{BMP} \times L_{BMP}$$
 (Equation 5-24)

where: L =

L_{removed} = Post-development pollutant load removed by proposed BMP (pounds per year)

Eff_{BMP} = pollutant removal efficiency of BMP (expressed in decimal form)

L_{BMP} = relative post-development total phosphorous load entering proposed BMP (pounds per year)

$$L_{removed/BMP1} =$$
______ pounds per year

$$L_{removed/BMP2} =$$
______ × ____ = _____ pounds per year

$$L_{removed/BMP3} =$$
______ pounds per year

Page 5 of 5

5. Calculate the total pollutant load removed by the BMP(s):

$L_{removed/total} = L_{removed/BMPI} +$	$L_{\text{removed/BMP2}} + L_{\text{removed/BMP3}} + \dots$ (Equation 5-25)
$\begin{array}{ll} \text{where:} & L_{\text{removed/total}} = \\ & L_{\text{removed/BMP1}} = \\ & L_{\text{removed/BMP2}} = \\ & L_{\text{removed/BMP3}} = \end{array}$	total pollutant load removed by proposed BMPs pollutant load removed by proposed BMP No. 1 pollutant load removed by proposed BMP No. 2 pollutant load removed by proposed BMP No. 3
$L_{removed/total} = +$	++
=po	ounds per year

6. Verify compliance:

$L_{removed/total}$	≥	RR		
		>		

Page 1 of 6

Summary of Situation 3 criteria: from calculation procedure STEP 1 thru STEP 3, Worksheet 1:

Applicable area (A) = acres

 $I_{\text{watershed}} = \frac{\%}{100} \text{ or } I_{\text{watershed}} = 16\%$

 $I_{\text{existing}} = \text{(total existing impervious cover} \div A^*) \times 100 = _________$

 $I_{\text{existing}} = \frac{0_0}{0} > I_{\text{watershed}} = \frac{0_0}{0}$

Summary of existing BMP:

Existing BMP drainage area $(A_{existBMP}) =$ _____ acres

EFF_{existBMP} = documented pollutant removal efficiency of existing BMP (expressed in decimal form)

STEP 4 Determine the relative pre-development pollutant load (L_{pre}).

1. Calculate pre-development pollutant load based on the existing impervious cover:

$$\mathbf{L}_{\text{pre(existing)}} = [0.05 + (0.009 \times I_{\text{existing}})] \times A \times 2.28 \quad \text{(Equation 5-17)}$$

where:

 $L_{pre(existing)}$ = relative pre-development total phosphorous load (pounds per year) $I_{existing}$ = existing site impervious cover (percent expressed in whole numbers)

A = applicable area (acres)

$$\mathbf{L}_{\text{pre(existing)}} = [0.05 + (0.009 \times \underline{})] \times \underline{} \times 2.28$$

$$= \underline{} \text{pounds per year}$$

Page 2 of 6

2. Calculate pre-development pollutant load to existing BMP:

$$\begin{aligned} \mathbf{L}_{\text{pre(BMP)}} &= [0.05 + (0.009 \times I_{\text{pre(BMP)}})] \times \mathbf{A}_{\text{existBMP}} \times 2.28 & \textbf{(Equation 5-18)} \\ \end{aligned}$$
 where:
$$\begin{aligned} \mathbf{L}_{\text{pre(BMP)}} &= & \text{relative pre-development total phosphorous load to existing BMP} \\ & & \text{(pounds per year)} \\ I_{\text{pre(BMP)}} &= & \text{existing impervious cover to existing BMP (percent expressed in whole numbers)} \\ \mathbf{A}_{\text{existBMP}} &= & \text{drainage area of existing BMP (acres)} \\ \end{aligned}$$

$$\mathbf{L}_{\text{pre(BMP)}} = [0.05 + (0.009 \times \underline{})] \times \underline{} \times 2.28 \end{aligned}$$

3. Calculate pre-development pollutant load removed by existing BMP:

= _____ pounds per year

Steps 2 and 3 are repeated for each existing BMP on the site.

Page 3 of 6

4. Calculate the pre-development pollutant load while being served by existing BMP(S):

$$L_{\text{pre(existingBMP)}} = L_{\text{pre(existing)}} - (L_{\text{removed(existingBMP1)}} + L_{\text{removed(existingBMP2)}} + L_{\text{removed(existingBMP3)}})$$
Equation 5-20

where: L_{pre(existingB)}

L_{pre(existingBMP)} = relative pre-development total phosphorous load while being

served by an existing BMP (pounds per year)

L_{pre(existing)} = relative pre-development total phosphorous load based on existing

site conditions, Equation 5-17 (pounds per year)

EFF_{existBMP} = documented pollutant removal efficiency of existing BMP

(expressed in decimal form)

 $L_{removed(existingBMP)}$ = relative pre-development total phosphorous load removed by

existing BMP, Equation 5-19 (pounds per year)

STEP 5 Determine the relative post-development pollutant load (L_{post}).

$$\mathbf{L_{post}} = [0.05 + (0.009 \times I_{post})] \times A \times 2.28 \quad \text{(Equation 5-21)}$$

where: L = relative post-development total pho

L_{post} = relative post-development total phosphorous load (pounds per

I_{post} = post-development percent impervious cover (percent expressed in whole numbers)

A = applicable area (acres)

$$L_{post} = [0.05 + (0.009 \times ____)] \times ___ \times 2.28$$
= _____ pounds per year

STEP 6 Determine the relative pollutant removal requirement (RR).

$$RR = L_{post} - L_{pre(existingBMP)}$$

$$= \underline{\qquad} - \underline{\qquad}$$

Page 4 of 6

2. Pre-development pollutant load based on the average land cover condition:

$$\mathbf{L}_{\text{pre(watershed)}} = [0.05 + (0.009 \times I_{\text{watershed}})] \times \mathbf{A} \times 2.28 \quad \text{(Equation 5-16)}$$

where:

 $L_{pre(watershed)}$ = relative pre-development total phosphorous load (pounds per year) $I_{watershed}$ = average land cover condition for specific watershed or locality or

average land cover condition for specific watershed or locality or the Chesapeake Bay default value of 16% (percent expressed in

whole numbers)

A = applicable area (acres)

$$\mathbf{L}_{\text{pre(watershed)}} = [0.05 + (0.009 \times \underline{})] \times \underline{} \times 2.28$$

$$= \underline{} \text{pounds per year}$$

STEP 7 Identify best management practice (BMP) for the site.

1. Determine the required pollutant removal efficiency for the site:

$$EFF = (RR \div L_{post}) \times 100 \qquad (Equation 5-22)$$

where:

EFF = required pollutant removal efficiency (percent expressed in whole numbers)

RR = pollutant removal requirement (pounds per year)

L_{post} = relative post-development total phosphorous load (pounds per vear)

2. Select BMP(s) from Table 5-15 and locate on the site:

BMP 1:_____

BMP 2:____

BMP 3: _____

Page 5 of 6

3. Determine the pollutant load entering the proposed BMP(s):

$$L_{BMP} = [0.05 + (0.009 \times I_{BMP})] \times A \times 2.28$$
 (Equation 5-23)

where:

L_{BMP} = relative post-development total phosphorous load entering proposed BMP (pounds per year)

I_{BMP} = post-development percent impervious cover of BMP drainage area (percent expressed in whole numbers)

A = drainage area of proposed BMP (acres)

$$L_{BMPI} = [0.05 + (0.009 \times ____)] \times ___ \times 2.28$$

= _____ pounds per year

$$L_{BMP2} = [0.05 + (0.009 \times ____)] \times ___ \times 2.28$$

= _____ pounds per year

$$L_{BMP3} = [0.05 + (0.009 \times ___)] \times ___ \times 2.28$$

= _____ pounds per year

4. Calculate the pollutant load removed by the proposed BMP(s):

$$L_{removed} = Eff_{BMP} \times L_{BMP}$$
 (Equation 5-24)

where:

L_{removed} = Post-development pollutant load removed by proposed BMP (pounds per year)

 Eff_{BMP} = pollutant removal efficiency of BMP (expressed in decimal form)

L_{BMP} = relative post-development total phosphorous load entering proposed BMP (pounds per year)

$$L_{removed/BMP1} =$$
______ × ____ = _____ pounds per year

$$L_{removed/BMP2} = \underline{\hspace{1cm}} \times \underline{\hspace{1cm}} = \underline{\hspace{1cm}}$$
 pounds per year

$$L_{removed/BMP3} =$$
 \times ____ = ___ pounds per year

Page 6 of 6

5. Calculate the total pollutant load removed by the existing and proposed BMP(s):

6. Verify compliance:

removed/total	2	KK	
		>	

URBAN LAND USE IMPERVIOUS COVER AND ANNUAL POLLUTANT LOAD

Representative Land Uses	Average Impervious Cover	Annual Pollutant Load(lb/ac/yr)
	0	0.11
	5	0.22
2-5 Acre Residential	10	0.32
	15	0.42
1 Acre Residential	20	0.52
1/2 Acre Residential	25	0.63
1/3 Acre Residential	30	0.73
1/4 Acre Residential	35	0.83
1/4 Acre Residential	40	0.94
1/8 Acre Residential	45	1.04
1/8 Acre Residential	50	1.14
	55	1.24
Townhouses/Garden Apartments	60	1.35
	65	1.45
Light Industrial	70	1.55
Light Industrial	75	1.65
	80	1.76
Haavy Industrial/Commercial	85	1.86
Heavy Industrial/Commercial	90	1.96
	95	2.06
Pavement	100	2.17

Note: The average impervious cover values may be used for estimating or planning purposes when considering the representative land use as shown. When possible, final design calculations should be based on actual percent impervious cover as measured from the site plan.

Chapter 12 - Environmentally Sensitive Areas

Stormwater discharges to areas with features identified as environmentally sensitive may be subject to additional requirements, or may need to utilize or restrict certain stormwater management practices. The County of Roanoke has designated the following type of areas as "environmentally sensitive":

- Floodplains Areas identified within a 100-year recurrence interval flood plain.
- Steep Slopes Areas with a slope of 33 percent or greater.
- Stream Buffers Setbacks and vegetative buffers established adjacent to the Roanoke River as required by the County of Roanoke zoning ordinance or designated conservation area buffer zones at each bank of streams, ponds, lakes, wetlands, and stormwater BMPs.
- Critical Erosion Areas Areas with potential serious erosion problems as defined in the VA E&SC Handbook. These fall into two sub categories.
 - The erosion hazard is critical if the slope length exceeds the following criteria:

0-7% slope > 300 feet 7-15% slope > 150 feet >15% slope > 75 feet

- Areas may be critical if the soils are highly erodible, as classified using the United States Department of Agriculture (USDA) Natural Resources Conservation Service (formerly Soil Conservation Service) methods, either Land Capability Classification IIIe, IVe, IV, VII, or VIII or with an erodibility index factor greater than 8.
- Karst Geology Areas where the underlying geologic conditions include caves and crevices which allow stormwater to infiltrate and quickly migrate and transport potential pollutants.
- Hot Spots Areas where a high potential for stormwater pollution may occur due to current or former activity on the site.

12.1 References

The following publications may be useful in providing guidance when performing construction, establishing development limits, and developing appropriate strategies and design features to address the special concerns related to environmentally sensitive areas:

- VDOT Drainage Manual
- VA E&SC Handbook
- VA SWM Handbook
- Virginia Department of Conservation and Recreation, Technical Bulletin No. 2, Hydrologic Modeling and Design in Karst
- International Building Code
- The Development of the Land Capability Classification (reprinted from Readings in the History of the Soil Conservation Service), Douglas Helms, Soil Conservation Service, 1992

12.2 Floodplains

The purpose of floodplain management is to regulate the use of the floodplains in order to protect life and property, prevent sedimentation and pollution of water resources, and to prevent or protect against the general degradation of the environment.

Floodplains and their regulatory requirements are generally based on the stream flows generated by a 100-year frequency storm and existing land development conditions. However, storms and future land development can generate flows of greater magnitude and flooding above and beyond these limits. For this reason, additional vertical and horizontal setbacks from the floodplain limits are strongly encouraged to account for future development within the upstream drainage area and to serve as a factor of safety for larger flood events.

Floodplains include:

- Areas identified within a 100-year recurrence interval floodplain as identified by the Federal Emergency Management Agency (FEMA). These areas have been identified as the Floodplain Overlay District by the County of Roanoke Zoning Ordinance.
- Areas identified within a 100-year interval floodplain as identified by an applicant floodplain study.

Management of floodplains in Roanoke County shall be in accordance with the requirements published in the County of Roanoke Zoning Ordinance.

Under no conditions, shall the land disturbance activity adversely affect the capacity of channels, floodways, ditches, or any drainage facility or system.

The lowest floor elevation of any new residential structure, as defined in the County of Roanoke Zoning Ordinance Section 30-28, shall be at least 2 feet above the base flood elevation. The lowest floor elevation of any new non-residential structure shall be at least 1 foot above the base flood elevation unless the structure is floodproofed. The elevation of the lowest floor shall be certified by a registered surveyor or professional engineer on an Elevation Certificate after the lowest floor is installed.

Grading and cut and fill operations within the 100-year flood plain are discouraged and must be approved by the County of Roanoke. Activity within the floodplain must also be coordinated with other regulatory requirements and agencies. These may include erosion and sediment control, stream buffer protection, FEMA, VMRC, US Army Corps of Engineers, Virginia DEQ, and others.

Construction of stormwater management impoundment structures within a floodplain shall be avoided to the extent possible. Where this is unavoidable, all stormwater management facility construction shall be in compliance with all applicable regulations under the National Flood Insurance Program, 44 CFR Part 59, and in accordance with the County of Roanoke Zoning Ordinance.

The County does not have the authority to alter or modify the flood limits and/or elevations established by FEMA. Should an applicant flood study indicate any alteration in FEMA's limits and/or elevations, then the applicant must contact FEMA and obtain a map revision.

12.2.1 Applicant Flood Study Requirements

A flood study must be prepared and submitted, by the applicant, for all areas where the drainage area is greater than 100 acres and there are no detailed flood profiles or elevations from a FEMA Flood Insurance Study.

There are two levels of studies. A detail study is required, if any development is proposed within the floodplain. Development includes grading and road crossings. A limited detail study is acceptable, if no development is proposed within the floodplain and the purpose of the study is to avoid the floodplain.

A detail study involves a rigorous detail hydrologic and hydraulic study of a flooding source reach. The typical riverine detail study includes the following minimum steps:

- Field survey of stream and floodplain cross-sections
- Field survey of all hydraulic structure crossings.
- Collection of historical high water mark elevations and model calibration/verification, if data is available.
- Detailed hydrologic & hydraulic modeling/computations
- Establishment of the FEMA regulatory Floodway

• Other tasks meeting all FEMA Guidelines and Specifications for Flood Hazard Mapping Partners (http://www.fema.gov/pdf/fhm/frm_gsac.pdf)

A limited detail study may be performed when development is to occur adjacent to, but not in the existing floodplain. In most limited detail modeling, local regional regression equations along with a HEC-RAS hydraulic model will be developed. The major difference between the HEC-RAS models for the limited detail study and the detail study will be the amount of field survey information collected in the field and used to create the model and the amount of time spent on calibration to historical flood elevations. The limited detail models typically include no field survey data, and floodways are typically not computed. The methods for limited detail study are further outlined in the FEMA Guidelines and Specifications for Flood Hazard Mapping Partners (htttp://www.fema.gov/pdf/fhm/frm_gsac.pdf)

In addition, the following information and items are required when an applicant flood study is submitted to Roanoke County for review:

- The flood study shall be based on the ultimate land use conditions as published in the most recent Comprehensive Plan. Structure locations shall be based on the ultimate build out data.
- The flood study shall be prepared by a registered Professional Engineer licensed to practice engineering in Virginia, sealed, signed, and dated.
- Assuming that sedimentation or scour may occur during the storm event is not acceptable.
- The flood study shall compare pre- and post-development conditions to verify that the proposed development will not increase the 100 year flood elevation more than 1 foot at any point.
- The flood study shall consider backwater conditions, local obstructions and, where required by the County of Roanoke Department of Community Development, the partial or complete failure of any enclosed drainage system. Consideration must be given to the overflow path, to ensure that no structures will flood in the event of system failure.
- The flood study shall analyze the 100-year flood path for all new development.
- A digital version of the 100-year flood limits must be supplied to the County. The study and supporting data will become property of the County.
- Cross sections from the study must be indicated on the site plans submitted as a part of the development review package.

12.2.2 Floodplain Delineation

The limits of floodplain floodways shall be staked in the field prior to any land disturbance activities and they shall remain undisturbed during construction. After the completion of construction, the limits of floodplain floodways shall be checked to verify that no unauthorized filling has taken place in the floodway.

Place floodplain limits and floodways on the final plats submitted for each property. All subdivision plats and site plans located within the floodplain in whole or in part shall include base flood elevation data

12.3 Steep Slopes

Special precautions and guidelines are required for development in areas having steep slopes, defined as thirty-three and one third percent (33.3%) or greater. These precautions and guidelines address the increased potential for soil erosion, sedimentation, water pollution and septic disposal problems associated with the development of areas with significant topographical relief. Unrestricted development of steep slopes may result in:

- Rapid and/or large-scale movement of soil and rock;
- Rapid and excessive stormwater run-off;
- Deposition of eroded material leading to siltation of natural and man-made bodies of water;
- Loss of aesthetic resource; and
- Greater travel distance of septic effluent in the event of septic system failure.

12.3.1 Development Restrictions

Land-disturbing activities on steep slopes are regulated by Chapter 8.1 of the County Code, "Erosion and Sediment Control and Steep Slope Development Ordinance of the County of Roanoke, Virginia."

If the grade of a site is greater than 33.3%, refer to the International Building Code for steep slope development requirements.

12.3.2 Design Standards

No land disturbance of steep slopes may occur without a geotechnical study that concludes that the land disturbance will result in a stable finished slope. For the requirements of a geotechnical study, see County of Roanoke Erosion and Sediment Control and Steep Slope Ordinance

Land disturbance of steep slopes require the preparation and submittal to the County of as-built plans showing that the finished geometry is in substantial conformity with the approved site plan.

Fill materials, compaction methods, and density specifications shall be indicated on the site development plans. Fill areas intended to support structures shall also be indicated on the site development plans. Compaction test results, per VDOT standards, shall be submitted to the County.

Site grading and measures required to control stormwater runoff shall collect and carry storm drainage away from the steep slope to the extent possible. If concentrated runoff is to be discharged in areas of steep slopes, adequate protection must be installed to prevent channel erosion and energy dissipation shall be used at the base of the steep slope to prevent erosion where the flow transitions to a shallower slope. The use of a closed conduit storm drain should be considered in accordance with Chapter 7.

12.4 Stream Buffers

Stream buffers are established to provide a naturally vegetated strip of land adjacent to a stream. This buffer protects the stream from encroachment by development, preserves the water, recreational, and environmental resources, protects the floodplain and floodway, retards runoff, and helps improve the water quality of stream by preventing erosion and filtering non-point source pollution from runoff.

The establishment of stream buffers as a water quality measure is encouraged by the County of Roanoke. Requirements for stream buffers shall be in accordance with the County of Roanoke Zoning Ordinance.

12.5 Critical Erosion Areas

Critical erosion areas, if cleared of vegetation and exposed to the elements of nature, may experience significant erosion and sedimentation problems, including a significant loss of topsoil. These soils tend to be located on hillsides and areas with steep slopes, and adjacent to river valleys and tributaries.

Critical erosion areas include two sub categories:

• The erosion hazard is critical if the slope length exceeds the following criteria:

0-7% slope > 300 feet 7-15% slope > 150 feet >15% slope > 75 feet

 Areas may be critical if the soils are highly erodible, as classified using the United States Department of Agriculture (USDA) Natural Resources Conservation Service (formerly Soil Conservation Service) methods, either Land Capability Classification IIIe, IVe, IV, VII, or VIII or with an erodibility index factor greater than 8.

The Erodibility Index (EI) for any soil is defined as the product of the formula RKLS/T

- K is the soil susceptibility to water erosion in the surface layer (from the local soil survey)
- o R is the rainfall and runoff rate, defined as 160 for Roanoke, Virginia
- LS is the combined effects of slope length and steepness (from the table in Appendix 12A)
- o T is the soil loss tolerance (from the local soil survey)

The current Soil Survey of Roanoke County and the Cities of Roanoke and Salem, Virginia, produced by the United States Department of Agriculture, National Resource Conservation Service shall be used to determine if a parcel is likely to have highly erodible soils, unless a more detailed geotechnical study is performed.

Critical erosion areas shall be indicated on the Erosion and Sediment Control Plan. To the extent feasible, disturbance of critical erosion areas shall be avoided or minimized. Where critical erosion areas are disturbed, their protection and stabilization shall specifically be addressed by the Erosion and Sediment Control Plan and the Stormwater Management Plan.

12.6 Karst Geology

Karst is an underlying geology which is common in Roanoke County where the underlying rock is predominantly soluble limestone or dolomite creating caves, crevices, and other cavities in the rock. Stormwater may infiltrate to the karst geologic rock and quickly drain through the open cavities. In addition to providing a quick transport mechanism for potential stormwater pollutants, this may create quick erosion of the limestone, potentially causing sinkholes or other surface sloughing.

Karst areas present problems with conventional hydrologic stormwater models, creating poor representation of runoff rates as most models do not have allowances for losses through sinkholes, crevices, or caves.

A site investigation is required to identify areas impacted by karst geology. Identification of karst in a land disturbance activity area shall be based on local geology and soils maps, aerial photography, and site visits by an individual familiar with karst geology.

See DCR Technical Bulletin #2, Hydrologic Modeling and Design in Karst for additional information on identification, and modeling requirements for areas in karst geology. Recommended practices include:

- Design the site to take maximum advantage of topography.
- Minimize site disturbance, cuts, fills, and drainage alterations.
- Minimize the impervious surface.
- Stormwater conveyance structures shall be designed to dissipate overland flow over the largest areas possible. Avoid concentration of flows and ponding.
- Infiltration facilities may not be located in karst geology.

12.7 Stormwater Hot Spots

Stormwater discharges from land uses or activities with higher potential pollutant loadings, known as "hotspots", may require a greater level of stormwater treatment or the use of specific structural BMPs and pollution prevention practices. Greater concentrations of sediment, hydrocarbons, traces metals, pesticides, and other toxics than are found in typical stormwater runoff may qualify a site for designation as a hot spot.

The following land uses and activities are designated as stormwater hotspots:

- 1. Vehicle salvage yards and recycling facilities;
- 2. Vehicle fueling stations;
- 3. Vehicle service and maintenance facilities;
- 4. Vehicle and equipment cleaning facilities;
- 5. Fleet storage areas (bus, truck, etc);
- 6. Industrial sites (for SIC codes contact VA DEQ);
- 7. Marinas (service and maintenance areas);
- 8. Outdoor liquid container storage;
- 9. Outdoor loading and unloading facilities;
- 10. Public works storage areas;
- 11. Facilities that generate or store hazardous materials;
- 12. Commercial container nursery;
- 13. Golf courses;
- 14. Chemical storage; and
- 15. Dry cleaning operations.

12.7.1 Design Restrictions

Stormwater BMP practices having an infiltration component are prohibited, even with pretreatment, in stormwater hotspot areas.

Stormwater detention facilities shall be separated a minimum of four feet from the seasonal high groundwater table, or utilize an impermeable liner.

The property owner must conform with all applicable laws and regulations relevant to any chemicals or hazardous materials used on these sites. Industrial operations shall be conducted to minimize exposure of chemical storage containers to stormwater, and contain any runoff as required by law where this can not be avoided.

These sites must also meet DCR VSMP and DEQ VPDES permit requirements, where applicable.

12.7.2 Golf Course Development

Golf courses, while maintaining impervious area and natural buffers allow for the introduction of nutrients into stormwater through fertilizers and chemicals into stormwater through the use of pesticides and herbicides.

Design of golf courses, public or private, shall meet the following performance standards:

- 1. Managed turf shall be reduced by including areas of rough devoted to native plants, natural environments, and wildlife habitat enhancement;
- 2. An Integrated Pest Management and nutrient management plan shall be submitted for review and approval;
- 3. Native or naturalized landscaping shall be used to the extent possible;
- 4. Natural vegetation and trees along streams shall be retained to the extend possible;
- 5. Stream crossings shall be minimized;
- 6. Irrigation, drainage and retention systems shall be designed to provide for efficient use of water and the protection of water quality;
- 7. Water reuse strategies shall be employed when feasible;
- 8. Adherence to the "Environmental Principles of Golf Courses in the United States" published by the Center for Resource Management is encouraged.

9. A Nutrient Management Plan shall be developed by a certified Nutrient Management Planner consistent with DCR's Nutrient Management Training and Certification Regulations.

APPENDIX 12A

DESIGN AIDS

FROM LOCAL ASSISTANCE MANUAL, CHESAPEAKE BAY LOCAL ASSISTANCE DEPARTMENT NOVEMBER 1989

Erodibility Index, Length/Slope (LS) Factors

LENGTH/SLOPE (LS) FACTORS

	Slope Length in Feet													
%	10	20	40	60	80	100	110	120	130	140	150	160	180	200
Slope														
0.2	0.04	0.05	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10
0.3	0.04	0.05	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11
0.4	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11
0.5	0.05	0.06	0.08	0.08	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12
1.0	0.06	0.08	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.16
2.0	0.10	0.12	0.15	0.17	0.19	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.25
3.0	0.14	0.18	0.22	0.25	0.27	0.29	0.30	0.30	0.31	0.32	0.32	0.33	0.34	0.35
4.0	0.16	0.21	0.28	0.33	0.37	0.40	0.42	0.43	0.44	0.46	0.47	0.48	0.51	0.53
5.0	0.17	0.24	0.34	0.41	0.48	0.54	0.56	0.59	0.61	0.63	0.66	0.68	0.72	0.76
6.0	0.21	0.30	0.43	0.52	0.60	0.67	0.71	0.74	0.77	0.80	0.82	0.85	0.90	0.95
8.0	0.31	0.44	0.63	0.77	0.89	0.99	1.04	1.09	1.13	1.17	1.21	1.25	1.33	1.40
10.0	0.43	0.61	0.87	1.06	1.23	1.37	1.44	1.50	1.56	1.62	1.68	1.73	1.84	1.94
12.0	0.57	0.81	1.14	1.40	1.61	1.80	1.89	1.98	2.06	2.14	2.21	2.28	2.42	2.55
14.0	0.73	1.30	1.45	1.78	2.05	2.29	2.41	2.51	2.62	2.72	2.81	2.90	3.08	3.25
16.0	0.90	1.27	1.80	2.20	2.54	2.84	2.98	3.11	3.24	3.36	3.48	3.59	3.81	4.01
18.0	1.09	1.54	2.17	2.66	3.07	3.43	3.60	3.76	3.92	4.06	4.21	4.34	4.61	4.86
20.0	1.29	1.82	2.58	3.16	3.65	4.08	4.28	4.47	4.65	4.83	5.00	5.16	5.47	5.77
25.0	1.86	2.63	3.73	4.56	5.27	5.89	6.18	6.45	6.72	6.97	7.22	7.45	7.90	8.33
30.0	2.52	3.56	5.03	6.16	7.11	7.95	8.34	8.71	9.07	9.41	9.74	10.06	10.67	11.25
40.0	4.00	5.66	8.00	9.80	11.32	12.65	13.27	13.86	14.43	14.97	15.50	16.01	16.98	17.30
50.0	5.64	7.97	11.27	13.81	15.94	17.82	18.69	19.53	20.32	21.09	21.83	22.55	23.91	25.21
60.0	7.32	10.35	14.64	17.93	20.71	23.15	24.28	25.36	26.40	27.39	28.36	29.29	31.06	32.74

	Slope Length in Feet													
%	300	400	500	600	700	800	900	1000	1100	1200	1300	1500	1700	2000
Slope														
0.2	0.11	0.12	0.13	0.14	0.15	0.15	0.16	0.16	0.17	0.17	0.18	0.19	0.19	0.20
0.3	0.12	0.13	0.14	0.15	0.16	0.16	0.17	0.18	0.18	0.18	0.19	0.20	0.21	0.22
0.4	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.19	0.20	0.20	0.21	0.22	0.23
0.5	0.14	0.15	0.16	0.17	0.18	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.24
1.0	0.18	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.27	0.28	0.29	0.30	0.32
2.0	0.28	0.31	0.33	0.34	0.36	0.38	0.39	0.40	0.41	0.42	0.43	0.45	0.47	0.49
3.0	0.40	0.44	0.47	0.49	0.52	0.54	0.56	0.57	0.59	0.61	0.62	0.65	0.67	0.71
4.0	0.62	0.70	0.76	0.82	0.87	0.92	0.96	1.01	1.04	1.08	1.12	1.18	1.24	1.33
5.0	0.93	1.07	1.20	1.31	1.42	1.52	1.61	1.69	1.78	1.86	1.93	2.07	2.21	2.40
6.0	1.17	1.35	1.50	1.65	1.78	1.90	2.02	2.13	2.23	2.33	2.43	2.61	2.77	3.01
8.0	1.77	1.98	2.22	2.43	2.62	2.81	2.98	3.14	3.29	3.44	3.58	3.84	4.09	4.44
10.0	2.37	2.74	3.06	3.36	3.62	3.87	4.11	4.33	4.54	4.74	4.94	5.30	5.65	6.13
12.0	3.13	3.61	4.04	4.42	4.77	5.10	5.41	5.71	5.99	6.25	6.51	6.99	7.44	8.07
14.0	3.98	4.59	5.13	5.62	6.07	6.49	6.88	7.26	7.61	7.95	8.27	8.89	9.46	10.26
16.0	4.92	5.68	6.35	6.95	7.51	8.03	8.52	8.98	9.42	9.83	10.24	11.00	11.71	12.70
18.0	5.95	6.87	7.68	8.41	9.09	9.71	10.30	10.86	11.39	11.90	12.38	13.30	14.16	15.36
20.0	7.07	8.16	9.12	9.99	10.79	11.54	12.24	12.90	13.53	14.13	14.71	15.80	16.82	18.24
25.0	10.20	11.78	13.17	14.43	15.59	16.66	17.67	18.63	19.54	20.41	21.24	22.82	24.29	26.35
30.0	13.78	15.91	17.79	19.48	21.04	22.50	23.86	25.15	26.38	27.55	28.68	30.81	32.80	
40.0	21.92	25.31	28.30	31.00	33.48									
50.0	30.87													
60.0														

Source: Virginia Dept. of Conservation and Historic Resources, Division of Soil and Water Conservation

Chapter 13 - Geotechnical Studies (RESERVED)

Chapter 14 - Maintenance of Stormwater Management Facilities

Proper maintenance of stormwater management facilities is essential to ensure proper long-term operation of these systems. Possible problems which may develop without proper maintenance include:

- Stormwater structures may become clogged with debris reducing flow capacity which may cause upstream flooding;
- Stormwater storage facilities may fill with sediment or debris reducing storage capacity and diminishing the ability of the facility to lower storm flows which may result in flooding downstream;
- BMPs may not remove pollutants at the design levels required to meet the water quality requirements.

Stormwater management facilities include detention and retention basins, bioretention trenches, grassed swales, and other BMPs that are intended to control stormwater runoff and change the characteristics of that runoff including, but not limited to, the quantity and quality, the period of release or the velocity of flow. Stormwater management facilities also include pipes and open channels, where the pipes and open channels are integral parts of the BMP (e.g. the pipes in a detention basin that convey flow from the outlet structure through an embankment to the discharge), and where the pipes and open channels are being used as BMPs to store or treat stormwater.

Pipes (culverts and storm drains) and open channels that do not store or treat stormwater and are not an integral part of a BMP are storm drainage systems and not stormwater management facilities.

Maintenance of stormwater management facilities are addressed in this Chapter. Maintenance of culverts, storm drains, and open channels that are not stormwater management facilities are addressed in their respective chapters.

The maintenance guidance provided in this chapter are the routine maintenance that should be anticipated for a typical BMP of the given type; however, they are not meant to be all-inclusive. It is the applicant's responsibility to provide a project specific maintenance plan and schedule that is made a part of the maintenance agreement.

14.1 Responsibility for Maintenance

Maintenance of stormwater management facilities is the responsibility of the permittee during construction until all work is completed, including final clean up and site stabilization, to the satisfaction of the County. At the completion of construction, maintenance of stormwater

COUNTY OF ROANOKE

management facilities becomes the responsible party or land owner's responsibility in accordance with the executed Maintenance Agreement.

The County is not responsible for maintaining private stormwater management facilities.

14.2 Maintenance Agreements

A legally binding maintenance agreement specifying the parties responsible for the proper maintenance of all stormwater management facilities shall be secured prior to issuance of any permits for land disturbance activities.

Responsibility for the operation and maintenance of stormwater management facilities, after the completion of construction, shall remain with the responsible party or property owner and shall legally pass to any successor or owner.

The maintenance agreement shall include a project specific appendix that lists all stormwater management facilities present on the property; the minimum frequency of inspections and maintenance, and the routine maintenance that is to be performed for each stormwater management facility. The project specific appendix to the maintenance agreement is to be prepared by the applicant and submitted to the County with the Stormwater Management Plan for review. The information contained within this Chapter and within the VA SWM Handbook may be used, by the applicant, as a guide in preparing the project specific appendix to the maintenance agreement; however, the maintenance requirements shall be written to be specific to the project. When landscaping is a component of the stormwater management facility, a project specific maintenance schedule for the landscaping shall be provided that is reflective of the plant species that are used. The landscaping maintenance schedule shall contain guidance regarding methods, frequency, and time of year for landscape maintenance and fertilization.

A sample Maintenance Agreement is included in Appendix 14A

In addition, the applicant shall also establish easements for stormwater management facilities to grant the County the right of access for periodic inspections as described in Chapters 3 and 15.

14.3 Maintenance Program

A consistent maintenance program is the best way to ensure that stormwater management facilities will continue to perform their necessary functions. The following components are common to many stormwater management facilities maintenance programs and shall be followed, where applicable.

Regular Inspections

Scheduled inspections and additional inspections after major storm events are necessary to understand the condition of the stormwater management facility and discover deficiencies so that they may be corrected.

• Vegetation Management

Most stormwater management facilities rely on vegetation to filter sediment from stormwater and to stabilize the ground surface of the BMP. Turf grass is the most common groundcover; however, some stormwater management facilities use woody vegetation and wetland plants to increase pollutant removal.

Mowing

Some stormwater management facilities may have no mow zones. Do not mow areas meant to stay natural. If mowing is allowed and desired, most grasses are hardiest if maintained as an upland meadow, with a blade height of 6 to 8 inches. If a shorter lawn is desired, additional lawn care will be needed to maintain turf health. Never cut grasses below a blade height of 4 inches. Grasses on embankments should be cut at least twice in the spring growing season, once in the summer, and twice in the fall growing season.

Grass clippings should be collected, removed from the BMP, and disposed of properly. Ideally grass clippings should be composted and used as fertilizer or mulch in an upland area. Grass clippings must never be dumped into streams, open channels, storm drains, ponds, or stormwater management facilities.

Fertilization

One of the primary purposes of most stormwater management facilities is to remove nutrients from stormwater; therefore, it is important to not over fertilize. Often fertilization is not required, especially if grass is maintained at a height of 6 to 8 inches. Only fertilize where necessary to maintain the health of vegetation and then take care to apply only the minimum that is required.

Pest and Weed Control

Avoid unnecessary pesticide and herbicide use. When required, use pesticides and herbicides in accordance with listed instructions and never allow spray to enter water as many of these chemicals are toxic to aquatic life in small concentrations.

Removing Accumulated Sediment

Vegetation surrounding stormwater management facilities is designed to trap sediment; therefore, vegetation is likely to become laden with sediment and bare spots may emerge. Bare spots should be raked, backfilled if needed, and covered with top soil. Disturbed areas should be reseeded and mulched. Excess material

should be removed and may be used as a mulch or soil supplement. If the soil becomes compacted, then aeration may be necessary.

Unwanted Vegetation

Embankments must be kept clear of woody plants (trees and bushes) because their roots could cause seepage or slope failure. Consistent mowing should control any unwanted vegetation.

• Slope, Embankment and Outlet Stabilization

Stable slopes and embankments are necessary to ensure that erosion does not add to water quality problems and that embankments do not breach. Maintaining a health stand of grasses on slopes and embankments and preventing the grown of deep rooted (trees and shrubs) vegetation on embankment areas are important. Animal burrows can also cause deterioration to embankments. Animal burrows should be filled in as soon as they are discovered. In some cases animal control may be needed to avoid excessive burrows. Outlet structures are particularly vulnerable to undercutting and erosion. A small problem, if it is not corrected, may quickly result in the need to replace an entire structure. Consult a professional engineer if sink holes, cracking, wet areas around the outlet pipe, pipe displacement, or rusting of the pipe is observed.

Debris and Litter Control

Regular debris and litter removal will reduce the chance of clogging outlet structures, prevent damage to vegetated areas, reduce mosquito breeding habitats, improve site appearance, and reduce conditions for excessive algae growth.

Mechanical Components

Some stormwater management facilities have mechanical components including valves, sluice gates, anti-vortex devices, fence gates, locks, and access hatches that require periodic maintenance.

Insect Control

The simplest way to control insects, particularly mosquitoes, is to avoid stagnant water. Most stormwater management facilities are designed to be dry within a short time after a rain event. If an insect problem develops in a detention basin or infiltration facility, then there is a maintenance issue that needs to be corrected. In stormwater management facilities, such as retention basins, that are designed to have a permanent pool of water insects may be controlled by the prompt removal of floatable debris and perhaps by introducing and maintaining a fish population.

• Access Road and Area Maintenance

Most stormwater management facilities are designed to be accessible by heavy machinery for maintenance and repairs. Access should be maintained by periodic removal of woody vegetation and upkeep of gravel areas.

• Sediment and Pollutant Removal

The primary purpose of many stormwater management facilities is the removal of sediments and nutrients (which are often attached to sediments). Sediment will naturally accumulate in a stormwater management facilities and must be periodically removed. The frequency of sediment removal will vary widely depending on the stormwater management facility's type and character of the contributing watershed. Removed sediments and pollutants should be properly disposed of in an upland area. They should be stabilized with vegetation so that they are not eroded by rainfall. Once sediment is removed, the stormwater management facility should be quickly restabilized, usually with vegetation. If maintenance operations disturb more than 5,000 square feet, an erosion and sediment control permit will be required before commencing work. Sediment and pollutant removal will usually take heavy equipment and is beyond the capabilities of most property owners without the assistance of appropriate contractors.

• Component Repair or Replacement

Eventually, like all infrastructure, stormwater management facilities' components will need to be repaired or replaced. Components may include inflow and outflow devices, trash racks and anti-vortex devices, valves, orifices, pipes, concrete structures, filter or infiltration media, earthworks such as embankments and side slopes

Following completion of construction, routine maintenance shall be performed on stormwater management facilities as required. The following maintenance guidance requirements are the maintenance requirements that should be anticipated for a typical BMP of the given type; however, depending on the actual site conditions additional maintenance may be required if it becomes evident that a stormwater management facility is not operating properly as designed.

If the County becomes aware that a stormwater management facility has not been adequately maintained, is not functioning properly, or has becomes a danger to public safety, public health, or the environment, the responsible party will be notified in writing. The responsible party shall then be required to address the deficiency issue within a reasonable time as identified in the written notice. Failure to address the deficiency issue may result in enforcement actions as set forth in Chapter 15 of this Manual.

More than one of the following maintenance guidelines may be applicable to a given BMP. As an example a detention basin might follow the maintenance guidelines for earthen embankments, principal spillways, emergency spillway, sediment forebay, landscaping, and detention basin.

14.3.1 Earthen Embankments

Earthen embankments are an integral part of many BMPs including detention and retention basins and constructed wetlands. For Earthen Embankments maintenance guidance, see Table 14.1.

Table 14.1 Earthen Embankments Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect earthen embankments for signs of settlement, seepage, woody vegetation growth, animal burrows, and good ground cover.	Annually
Vegetation Management	 Objective is to maintain a healthy grass cover free of trees and brush Mow grass on embankments to a height of 6 to 8 inches. Remove all trees and brush from embankment and at least 25' beyond embankment. When removing trees and brush, extract as much of the root as possible. Fertilize, lime, or treat with pesticide or herbicide when needed to maintain grass health (do not over fertilize). Reseed embankments as necessary to maintain vegetation. Avoid over-fertilization. 	Mow grass on embankments at least twice during both growing seasons and once during the summer.
Slope, Embankment, and Outlet Stabilization	 Fill animal burrows with compacted fill. Regrade, repair, and revegetate eroded embankments. If there are signs of seepage or embankment slumps consult with a professional engineer. 	As needed based on damage observed during routine maintenance or inspections
Debris and Litter Control	Keep the embankment clear of debris and litter	During inspections or mowing
Mechanical Components	Not applicable	Not applicable
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Remove woody plants and maintain surface in drivable condition	Annually
Sediment and Pollutant Removal	Not applicable	Not applicable
Component Repair and Replacement	Replace embankments that have major erosion, seepage, or slumping problems. Consult with a professional engineer.	Infrequent

14.3.2 Principal Spillways

Principal Spillways are an integral part of many BMPs including detention and retention basins and constructed wetlands. Principal spillways normally consist of an outlet structure, pipe through an embankment, and outlet discharging to a downstream open channel. For guidance for the maintenance of Principal Spillways, see Table 14.2.

Table 14.2 Principal Spillways Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect outlet structure for signs of cracks, spalling, broken or loose sections, or leakage, and corrosion or damage to anti-vortex device or trash rack; inspect pipe for signs of corrosion or settling; inspect outlet protection for signs of erosion or damage.	Semiannually and after every major storm event inspect the outlet structure, pipe, and outlet protection.
Vegetation Management	Not applicable	Not applicable
Slope, Embankment, and Outlet Stabilization	Repair any erosion damage to outlet protection.	As needed based on damage observed during routine inspections
Debris and Litter Control	Keep outlet structure clear of debris. Remove debris from the BMP and properly dispose of in an upland area.	Semiannually and after major rain events as a minimum. Debris removal may be more frequent.
Mechanical Components	If a drain valve is present, exercise the valve semiannually to insure proper function. Periodically lubricate the stem and paint exposed metal to protect from corrosion.	As noted
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Remove woody plants and maintain surface in drivable condition	Annually
Sediment and Pollutant Removal	Not applicable	Not applicable
Component Repair and Replacement	Repair or replace outlet structure components to correct leakage, cracks, spalling, broken or loose sections, or corrosion. Repair or replace pipe to correct settlement, leakage, or corrosion. Repair or replace outlet protection to correct erosion damage. Take care to avoid changing the BMP discharge characteristics and to avoid damage to the embankment. Repairs and replacements may require consulting a professional engineer.	Infrequently

14-7

14.3.3 Emergency Spillway

Emergency Spillways are an integral part of many BMPs including detention and retention basins and constructed wetlands. Emergency spillways normally consist of an open channel, usually trapezoidal in cross-section, which are constructed beside an embankment to carry stormwater discharge from the BMP that is too great to be carried by the principal spillway. Emergency spillways only discharge stormwater very infrequently (usually not more frequently than once every ten years). Emergency spillways are most often vegetated (grassed), but may be protected against erosion by rip rap or concrete. For Emergency Spillways maintenance guidance, see Table 14.3.

Table 14.3 Spillway Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections		Annually, and after any rain event that results in flow through the emergency spillway.
Vegetation Management	 For a vegetated spillway the objective is to maintain a healthy grass cover free of trees and brush Mow grass to a height of 6 to 8 inches. Remove all trees and brush from spillway. When removing trees and brush, extract as much of the root as possible. Fertilize, lime, or treat with pesticide or herbicide when needed to maintain grass health (do not over fertilize). Reseed spillway as necessary to maintain vegetation. Avoid over-fertilization. 	Mow grass at least twice during both growing seasons and once during the summer.
Slope, Embankment, and Outlet Stabilization	Repair any damage to outlet.	As needed based on damage observed during routine inspections
Debris and Litter Control	Keep the emergency spillway clear of debris and litter.	During inspections or mowing
Mechanical Components	Not applicable	Not applicable.
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Remove woody plants and maintain surface in drivable condition	Annually
Sediment and Pollutant Removal	Not applicable	Not applicable
Component Repair and Replacement	Repair slopes and protective linings as needed.	Infrequently

14.3.4 Sediment Forebay

A sediment forebay is used as a pretreatment device to allow sediment to settle from the incoming stormwater runoff before it enters the balance of the BMP. A sediment forebay helps to isolate the sediment deposition in an accessible area, which facilitates BMP maintenance.

For Sediment Forebay maintenance guidance, see Table 14.4.

Table 14.4 Sediment Forebay Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Observe depth of sediment deposition	Annually
Vegetation Management	Not applicable	Not applicable
Slope, Embankment, and Outlet Stabilization	Not applicable	Not applicable
Debris and Litter Control	Remove debris and litter that accumulates in the sediment forebay	During inspections or as needed intermittently
Mechanical Components	Not applicable	Not applicable
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Remove woody plants and maintain surface in drivable condition	Annually
Sediment and	Remove accumulated sediment. Dispose of	Generally every 3 – 5
Pollutant Removal	sediments in an upland area and stabilize with	years or when $6 - 12$
	vegetation. If necessary, obtain erosion and	inches of sediment
	sediment control permit, prior to performing land disturbance.	has accumulated.
Component Repair and Replacement	Not applicable	Not applicable

14.3.5 Landscaping

Landscaping is an integral part of many BMP's. It is important that the landscaping thrive in order for it to fully function for pollutant uptake and ground stabilization.

For Landscaping maintenance guidance, see Table 14.5.

Table 14.5 Landscaping Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Observe landscaping growing conditions. If landscaping is not thriving, correct conditions by applying fertilization, pesticide, herbicide, or soil amendment.	Monthly during the first growing season. Annually, in the fall, thereafter.
Vegetation Management	Each site shall have a site specific landscape maintenance schedule, depending on the species used, that includes guidance regarding methods, frequency, and time of year for landscape maintenance and fertilization.	Varies. Different plant communities will require different levels of maintenance.
Slope, Embankment, and Outlet Stabilization	Not applicable	Not applicable
Debris and Litter Control	Remove debris and litter.	During inspections or as needed intermittently during vegetation management.
Mechanical Components	Not applicable	Not applicable
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Not applicable	Not applicable
Sediment and Pollutant Removal	Not applicable	Not applicable
Component Repair and Replacement	Provide reinforcement planting after the first growing season, if necessary. Thereafter, replace landscaping that dies or fails to thrive.	As needed based on observation during inspections

14.3.6 Stormwater Detention and Retention Basins

For the design of basins for stormwater quantity control see Chapter 9. For the design of basins for stormwater quality control, see Chapter 11.

For maintenance guidance of stormwater basins, refer to the maintenance guidance for Earthen Embankments, Principal Spillways, Emergency Spillways, Sediment Forebay, and Landscaping contained in this chapter.

For additional maintenance guidance for basins, see Table 14.6.

Table 14.6 Basins Maintenance (1)

Required Action	Maintenance Objective	Frequency of Action
Inspections	(1)	(1)
Vegetation	(1)	(1)
Management		
Slope, Embankment,	(1)	(1)
and Outlet		
Stabilization		
Debris and Litter	Keep the embankment clear of debris	During inspections or mowing
Control	and litter	
Mechanical	(1)	(1)
Components		
Insect Control	(1)	(1)
Access Road and	(1)	(1)
Area Maintenance		
Sediment and	(1), also remove accumulated sediment	(1), Depending on the
Pollutant Removal	from basin area. Dispose of sediments	effectiveness of the sediment
	in an upland area and stabilize with	forebay and the condition of the
	vegetation. If necessary, obtain erosion	watershed, sediment removal
	and sediment control permit, prior to	from the basin may be required
	performing land disturbance.	every 5 – 10 years.
Component Repair	(1)	(1)
and Replacement		

⁽¹⁾ Refer to the maintenance guidelines for Earthen Embankments, Principal Spillways, Emergency Spillways, Sediment Forebay, and Landscaping contained in this chapter.

COUNTY OF ROANOKE 9/11/07

MAINTENANCE

14.3.7 Constructed Wetlands

For use of constructed wetlands as a BMP, see Chapter 11. For constructed wetlands maintenance guidance, refer to the maintenance guidance for Earthen Embankments, Principal Spillways, Emergency Spillways, Sediment Forebay, and Landscaping contained in this chapter.

For additional maintenance guidance for constructed wetlands, see Table 14.7.

Table 14.7 Constructed Wetlands⁽¹⁾

Required Action	Maintenance Objective	Frequency of Action
Inspections	(1), Document plant species distribution and fatality rates and verify compliance with landscaping requirements; document sediment accumulations, water elevations, and condition of the outlet.	(1), Inspect at least semiannually for the first 3-years.
Vegetation	(1)	(1)
Management Slope, Embankment, and Outlet Stabilization	(1)	(1)
Debris and Litter Control	Keep the embankment clear of debris and litter	During inspections or as needed intermittently
Mechanical Components	(1)	(1)
Insect Control	(1)	(1)
Access Road and Area Maintenance	(1)	(1)
Sediment and Pollutant Removal	(1), As necessary, remove accumulated sediment from constructed wetland area and re-establish vegetation. Dispose of sediments in an upland area and stabilize with vegetation. If necessary, obtain erosion and sediment control permit, prior to performing land disturbance.	(1), Depending on the effectiveness of the sediment forebay and the condition of the watershed, sediment removal from the constructed wetland may be required infrequently (every 10 years or less frequent).
Component Repair and Replacement		(1)

⁽¹⁾ Refer to the maintenance guidelines for Earthen Embankments, Principal Spillways, Emergency Spillways, Sediment Forebay, and Landscaping contained in this chapter.

COUNTY OF ROANOKE
9/11/07 14-12

14.3.8 Infiltration Practices

For the design of infiltration basins and infiltration trenches as BMPs for stormwater quality, see Chapter 11 of this Design Manual.

14.3.8.1 Infiltration Basin

For Infiltration Basin maintenance guidance, refer to the maintenance guidance for Earthen Embankments, Principal Spillways, Emergency Spillways, Sediment Forebay, and Landscaping contained in this chapter. For additional maintenance guidance for infiltration basins, see Table 14.8A.

Table 14.8A
Infiltration Basin Maintenance (1)

Required Action	Maintenance Objective	Frequency of Action
Inspections	(1), Inspect basin to ensure that the basin functions as designed. Examine infiltration basin and outlet for clogging. Inspect for erosion, slumping, excessive sedimentation levels and vegetation overgrowth.	(1), Monthly for the first 6-months; and thereafter semiannually and after major rain events.
Vegetation Management	(1)	(1)
Slope, Embankment, and Outlet Stabilization	(1)	(1)
Debris and Litter Control	Keep the buffer area clean to reduce litter and floatables minimizing the clogging of the infiltration basin.	During inspections or mowing
Mechanical Components	Ensure no standing water remains in basin after storm events. Standing water indicates infiltration is clogged.	Repair as needed based on observation during semiannual inspection.
Insect Control	Remove accumulated sediment in basin and restore filtration area. If standing water is present during dry weather, the infiltration basin has become clogged.	Remove sediment accumulation every 2 years or when infiltration basin has standing water.
Access Road and Area Maintenance	(1)	(1)
Sediment and Pollutant Removal	Sediment shall be removed and disposed in an upland area and stabilized with vegetation when sediment fills the sediment reserve capacity, or when the basin loses its infiltration capacity. If necessary, obtain erosion and sediment control permit, prior to performing land disturbance. Avoid compacting the floor of the infiltration basin.	Depending on the effectiveness of the sediment forebay and the condition of the watershed, sediment removal may be required infrequently (every 10 years or less frequent).
Component Repair and Replacement	(1)	(1)

⁽¹⁾ Refer to the maintenance guidelines for Earthen Embankments, Principal Spillways, Emergency Spillways, Sediment Forebay, and Landscaping contained in this chapter.

COUNTY OF ROANOKE

14.3.8.2 Infiltration Trench

For maintenance requirements of infiltration trenches, see Table 14.8B.

Table 14.8B Infiltration Trench Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect infiltration trenches to ensure that the BMP continues to function as initially intended. Examine for clogging of infiltration trench. Document depth of water in observation well or assessable pretreatment device to assess dewater capacity of the facility.	Quarterly inspection for the first year, and semiannual inspection thereafter
Vegetation Management	Buffer strips shall be mowed to 4 to 6 inches to limit unwanted vegetation.	Cut grass twice during both growing seasons and once during the
	Trees shall be pruned such that the drip line does not extend over the surface trench. All trees shall be removed within the trench to	summer. Prune overhanging
	prevent the puncture of filter fabric.	trees annually.
Slope, Embankment, and Outlet Stabilization	Regrade, repair, and revegetate eroded and slumped buffer strips.	As needed based on damage observed during inspections.
Debris and Litter Control	Keep the buffer area clean to reduce litter and floatables minimizing the clogging of the infiltration trench.	During inspections or mowing
Mechanical Components	Not applicable.	Not applicable
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Remove woody plants and maintain surface in drivable condition	Annually
Sediment and Pollutant Removal	Remove accumulated sediment in infiltration trench and restore filtration area.	Every 2 years or when sediment causes infiltration trench to have standing water.
Component Repair and Replacement	Remove and replace top 6"-12" gravel and filter cloth sediment barrier.	As needed based on observation during inspections.

14.3.8.3 Porous Pavement

For the design of porous pavement as a BMP for stormwater quality, see Chapter 11.

For maintenance requirements of porous pavement, see Table 14.8.C.

Table 14.8.C Porous Pavement Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect pavement to ensure proper structural operation, and that the permeable aspect of the pavement has not become clogged with debris. Measure water depth in storage layer	Quarterly, and after every major rain events, until performance characteristics of the structure has been verified; thereafter, annually
Vegetation Management	Not applicable	Not applicable
Slope, Embankment, and Outlet Stabilization	Not applicable	Not applicable
Debris and Litter Control	Vacuum clean pavement surface, followed by high pressure water washing. Do not use sand or other abrasives during winter weather as they will clog the surface.	Monthly
Mechanical Components	Not applicable	Not applicable
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Not applicable	Not applicable
Sediment and Pollutant Removal	Not applicable	Not applicable
Component Repair and Replacement	No repair is possible. If pavement becomes clogged, complete replacement is required.	Depends on frequency and thoroughness of pavement cleaning

14.3.9 Bioretention Filter

For the design of bioretention filters as BMPs for stormwater quality, see Chapter 11. For maintenance guidance for bioretention filters, see Table 14.9.

Table 14.9 Bioretention Filter Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect filter to ensure that it continues to function as initially intended. Observe sedimentation, standing water, and vegetation.	Semiannually
Vegetation	Provide adequate fertilization, pruning,	Varies depending on plant
Management	and other care for landscaping.	species
Slope,	Not applicable	Not applicable
Embankment, and Outlet Stabilization		
Debris and Litter Control	Remove debris and litter.	During inspections
Mechanical Components	Not applicable	Not applicable
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Not applicable	Not applicable
Sediment and	Remove accumulated sediments and	Annually
Pollutant Removal	dispose of them in an upland location and stabilize with vegetation.	
Component Repair and Replacement	Replace mulch layer. On an as needed basis replace the planting soil and vegetation to restore infiltration capacity to the underdrain.	Every 2 years for routine mulch replacement. Every 5 years for planting soil replacement.

14.3.10 Sand Filters

For the design of sand filters as a BMP for stormwater quality, see Chapter 11. For maintenance guidance for sand filters, see Table 14.10.

Table 14.10 Sand Filter Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Monitor and document water level in filter chamber and rate of dewatering after storm events.	Quarterly and after each major rain event for the first year, semiannually and after each major rain event thereafter.
Vegetation Management	Not applicable	Not applicable
Slope, Embankment, and Outlet Stabilization	Not applicable	Not applicable
Debris and Litter Control	Not applicable	Not applicable
Mechanical Components	Not applicable	Note applicable
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Remove woody plants and maintain surface in drivable condition	Annually
Sediment and Pollutant Removal	Pump out sedimentation chamber. If water has an oil skim, it should be removed by a firm specializing in oil recovery and recycling. Remove sediments and dispose of them properly in an appropriate landfill. Refill the first chamber with water to restore the water seal.	Semiannually (midway between semiannual inspection events)
Component Repair and Replacement	Remove and replace filter cloth and ballast gravel to restore filtering capacity when filter will no longer draw down within 40-hours.	Varies depending on the efficiency of the pretreatment device

14.3.11 Grassed Swale

For use of grassed swales as a BMP, see Chapter 11. For grassed swale maintenance guidance, see Table 14.11.

Table 14.11 Grassed Swale Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Check for uniformity of vegetative cover or for structural repair needed for concrete linings. Check for sediment and debris accumulation and for erosion problems or bank sloughing.	 Weekly, until vegetation is established. Thereafter, semiannually. In addition, inspect grassed swale for damage after major rain events.
Vegetation	Objective is to maintain a healthy uniform	Mow grass periodically.
Management	vegetative growth:	Reseed as necessary.
	Use proper mowing techniques.	
	• Mow grass to a height of 6 inches.	
	Collect and remove grass clippings.	
	Periodic weeding of invasive species and	
	weeds.	
	Fertilize or treat with pesticide or herbicide	
	when needed to maintain plant health (do not	
	over fertilize).	
Clara Frahanlanant	Reseed and mulch any bare areas.	A 1 - 1 1 1 1 1
Slope, Embankment, and Outlet	Regrade, repair, and revegetate eroded and slumped areas. Repair channel lining, outlet	As needed based on damage observed.
Stabilization	protection and rip rap where required.	observed.
Debris and Litter	Keep the channel clean to reduce litter and	During inspections or
Control	floatables being washed downstream.	mowing
Mechanical	Not applicable	Not applicable
Components		тос прриспете
Insect Control	Not applicable	Not applicable
Access Road and	Not applicable	Not applicable
Area Maintenance		
Sediment and	Remove accumulated sediment in channels,	Depends on site conditions
Pollutant Removal	behind check dams, and at outfalls and culverts to	perform annually at a
	maintain flow capacity and drainage. Repair any	minimum.
	damage that occurs during sediment removal.	
Component Repair	Repair or replace check dams to maintain	Annually or as needed
and Replacement	temporary ponding and to maintain filtered flow	
	through check dams.	

COUNTY OF ROANOKE

14.3.12 Vegetated Filter Strip

For use of vegetated filter strips as a BMP, see Chapter 11. For vegetated filter strip maintenance requirements, see Table 14.12.

Table 14.12 Vegetated Filter Strip

Required Action	Maintenance Objective	Frequency of Action
Inspections	Check the vegetation for uniformity of cover, sediment and debris accumulation, and erosion. Check for proper operation of level spreader, if present.	 Weekly, until vegetation is established. Thereafter, semi-annually. In addition, inspect filter strip for damage after major rain events.
Vegetation Management	 Objective is to maintain a healthy uniform vegetative growth: If the area is maintained as lawn use proper mowing techniques. Collect and remove grass clippings. Periodic weeding of invasive species and weeds. Periodic pruning of woody vegetation to stimulate grown. Fertilize, lime, or treat with pesticide or herbicide when needed to maintain plant health (do not over fertilize). 	As dictated by conditions.
Slope, Embankment, and Outlet Stabilization	Regrade, repair, and revegetate eroded ground surface.	As needed based on damage observed during inspection
Debris and Litter Control	Keep the vegetated strip clean to reduce litter and floatables being washed downstream.	During inspections or mowing
Mechanical Components	Not Applicable.	Not Applicable.
Insect Control	Not Applicable.	Not Applicable
Access Road and Area Maintenance	Not Applicable.	Not Applicable
Sediment and Pollutant Removal	Remove accumulated sediment and reestablish vigorous vegetation cover. Dispose of sediments in an upland area and stabilize with vegetation. If necessary, obtain erosion and sediment control permit, prior to performing land disturbance.	Depends on site conditions perform annually at a minimum.
Component Repair and Replacement	If level spreader is used, replace rigid lip when necessary.	Infrequently

COUNTY OF ROANOKE

14.3.13 Manufactured BMP Systems

Several manufacturers have developed filter and screening devices which are gaining acceptability from the regulators as suitable BMPs for meeting stormwater quality requirements. These devices filter debris and sediment and other pollutants, such as metals and hydrocarbons from stormwater.

Specific maintenance requirements for manufactured BMPs shall be in accordance with the manufacturer's specifications and warranty requirements. See Table 14.13 for general maintenance guidance.

Table 14.13 Manufactured BMP Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect structure and inlets and outlets to ensure structural integrity and proper functioning of the facility.	Semiannual or as specified by the manufacturer.
Vegetation Management	Not applicable	Not applicable
Slope, Embankment, and Outlet Stabilization	Not applicable	Not applicable
Debris and Litter Control	Remove debris and litter that interferes with proper operation.	As needed based on impacts observed during semiannual inspection.
Mechanical Components	Provide routine maintenance to valves, sluice gates, pumps or other mechanical devices per manufacturer's instructions.	Per manufacturer's instructions.
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Not applicable	Not applicable
Sediment and Pollutant Removal	Clean manufactured screen or filter vault of debris, litter and floatable materials. Remove any sediment and pollutant build-up from the vault.	Annually or as required.
Component Repair and Replacement	Repair or replace tank or vault structure if leaks or cracks develop. Replace filtering media when necessary for proper functioning.	As recommended by the manufacturer and as needed.

14-20

14.3.14 Conservation Areas

Conservation areas are naturally vegetated areas used to provide a measure of stormwater quality control. Conservation Areas should be maintained in their natural condition. For Conservation Areas maintenance guidance, see Table 14.14.

Table 14.14 Conservation Areas Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Check the vegetation for uniformity of cover and growth, sediment and debris accumulation, and erosion.	 Quarterly, until vegetation is established. Thereafter, annually. In addition, inspect area for damage after major storm events.
Vegetation Management	(1) Weed control to promote survival and rapid growth of trees and shrubs.	If establishing new vegetation, continuous over first two years until vegetation is established. Vegetation shall be undisturbed after it has become established.
Slope, Embankment, and Outlet Stabilization	(2) Regrade, repair, and revegetate eroded and slumped banks.	As needed, based on damage observed during inspections.
Debris and Litter Control	Keep the area clean to reduce litter and floatables being washed downstream.	Annually, and after major storm events, clean debris and litter which has accumulated.
Mechanical Components	Not Applicable	Not applicable
Insect Control	Normally not applicable.	Normally not applicable.
Access Road and Area Maintenance	Normally not applicable.	Normally not applicable.
Sediment and Pollutant Removal	Normally not applicable. If heavy accumulations of sediment occur, then either remove sediment accumulation or stabilize sediment accumulation in place with top soil and additional vegetation plantings.	Infrequent
Component Repair and Replacement	Normally not applicable. If major areas lose trees due to fire, disease, or other cause, then replanting may be needed.	Rare

- (1) Note that most herbicides are very toxic to aquatic organisms. Follow listed instructions and never allow spray to enter waterways.
- (2) If maintenance work is required along the banks of jurisdictional streams or in wetlands, a permit may be required from the U.S. Army Corps of Engineers and the Virginia Department of Environmental Quality.

COUNTY OF ROANOKE

14.3.15 Underground Detention Facilities

Underground detention facilities are facilities that provide detention in underground pipes or chambers.

For underground detention maintenance guidance, see Table 14.15.

Table 14.15 Underground Detention Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect condition of storage facility, outlet structure, and presence of sediment and	Semiannually
	debris.	
Vegetation	Not applicable	Not applicable
Management		
Slope, Embankment,	Not applicable	Not applicable
and Outlet		
Stabilization		
Debris and Litter	Remove debris and litter.	As needed based on
Control		observations during
		semiannual inspection.
Mechanical	Not applicable	Not applicable
Components		
Insect Control	Not applicable	Not applicable
Access Road and	Not applicable	Not applicable
Area Maintenance		
Sediment and	Remove accumulated sediments and	Varies, depending on the
Pollutant Removal	dispose of them in an upland location and	effectiveness of the
	stabilize with vegetation.	pretreatment device.
Component Repair	Replace failed pipe, storage chambers, or	Rare
and Replacement	other components.	

14.3.16 Oil Water Separator

Oil water separators shall be used where oils, lubricants, or other petroleum-based chemicals may come into contact with stormwater runoff.

Oil water separators shall be maintained to properly operate and remove oils and greases from water. See Table 14.16 for maintenance guidance for oil water separators.

Table 14.16 Oil Water Separator Maintenance

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect tank structure and inlets and outlets to ensure proper functioning of the facility. Monitor oil level.	Quarterly
Vegetation Management	Not applicable	Not applicable
Slope, Embankment, and Outlet Stabilization	Not applicable	Not applicable
Debris and Litter Control	Keep the pre-treatment units and oil- water separator free of debris, litter and floatables to minimize clogging of the outlet.	Quarterly
Mechanical Components	Provide routine maintenance to valves, sluice gates, pumps or other mechanical devices per manufacturer's instructions.	Per manufacturer's instructions.
Insect Control	Not applicable	Not applicable
Access Road and Area Maintenance	Not applicable	Not applicable
Sediment and Pollutant Removal	Remove any sediment build-ups from oil-water separator or pretreatment device if necessary. Remove oil or grease from oil-water	Whenever oil level reaches 75% of full capacity.
	separator.	
Component Repair and Replacement	Replace tank if leaks or cracks develop.	Rare.

14.4 Additional Maintenance and Repairs

The routine maintenance items listed hereinbefore are the minimum measures. If actual conditions demonstrate that additional maintenance or repairs are necessary for proper functioning of the stormwater management systems, they shall be provided by the responsible party.

14.5 Inspection and Maintenance Records

The responsible party or property owner shall maintain records of stormwater management facilities' inspections and maintenance activities, and submit copies to the County, in accordance with the requirements of Chapter 15.

14.6 References

Maintaining Your BMP, A Guidebook for Private Owners and Operators in Northern Virginia, Northern Virginia Planning District Commission, Division of Environmental Services, February 2000 is a good reference for maintenance of private BMPs and this document is included in Appendix 14B.

APPENDIX 14A

MAINTENANCE AGREEMENTS

Stormwater Management/BMP Facilities – Sample Maintenance Agreement

Stormwater Management/BMP Facilities Maintenance Agreement

Maintenance Agreements shall be submitted to:

Department of Community Development Roanoke County Administration Center 5204 Bernard Drive P.O. Box 29800 Roanoke, VA 24018-0798

<u>Procedures for submitting agreements:</u>

- Obtain an <u>original</u> agreement form from this appendix or from the Department of Community Development (fax copies are unacceptable).
- <u>Type</u> all information on the agreement form.
- Sign form in <u>black ink</u>.
- Signature must be properly notarized (<u>black ink</u>).
- Attach a check for the recordation fee.
- The Department of Community Development will coordinate the County Attorney and County Executive signatures, and recordation.

STORMWATER MANAGEMENT/BMP FACILITIES MAINTENANCE AGREEMENT

THIS AGREEMENT, made and entered into this day of, 20
between hereinafter called
(Insert Full Name of Owner)
the "Landowner", and the Board of Supervisors of Roanoke County, Virginia, hereinafter calle
the "County". WITNESSETH, that WHEREAS, the Landowner is the owner of certain rea
property described as:
recorded by deed in
(Roanoke County Tax Map/Parcel Identification Number)
the land records of Roanoke County, Virginia, Deed Book Page, hereinafte
called the "Property".
WHEREAS, the Landowner is proceeding to build on and develop the property; an
WHEREAS, the Site Plan/Subdivision Plan known as
(Name of Plan/Development), hereinafter called the "Plan", which is expressl
made a part hereof, as approved or to be approved by the County, provides for treatment of
stormwater within the confines of the property; and

WHEREAS, the County and the Landowner, its successors and assigns, including any homeowners association, agree that the health, safety, and welfare of the residents of Roanoke County, Virginia, require that on-site stormwater management/BMP facilities be constructed and maintained on the Property; and

WHEREAS, the County requires that on-site stormwater management/BMP facilities as shown on the Plan be constructed and adequately maintained by the Landowner, its successors and assigns, including any homeowners association.

NOW, THEREFORE, in consideration of the foregoing premises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows:

- 1. The on-site stormwater management/BMP facilities shall be constructed by the Landowner, its successors and assigns, in accordance with the plans and specifications identified in the Plan.
- 2. The Landowner, its successors and assigns, including any homeowners association, shall adequately maintain the stormwater management/BMP facilities. This includes all pipes and channels built to convey stormwater to the facility, as well as all structures, improvements, and vegetation provided to control the quantity and quality of the stormwater. Adequate maintenance is herein defined as good working condition so that these facilities are performing their design functions.

- 3. The Landowner, its successors and assigns, shall periodically inspect the stormwater management BMP facilities. The purpose of the inspection is to assure safe and proper functioning of the facilities. The inspection shall cover the entire facilities, berms, outlet structure, pond areas, access roads, etc. Deficiencies shall be noted in the inspection report.
- 4. The Landowner, its successors and assigns, shall document all inspections, maintenance activities and repairs that are performed on the stormwater management BMP facilities. Documents shall be maintained for a minimum period of five (5) years and they shall be made available for review by, or copies shall be provided to, the County upon request.
- 5. The Landowner, its successors and assigns, hereby grant permission to the County, its authorized agents and employees, to enter upon the Property and to inspect the stormwater management/BMP facilities periodically and whenever the County deems necessary. The purpose of inspection is to verify that proper maintenance is occurring and/or to follow-up on reported deficiencies and/or to respond to citizen complaints. The County shall provide the Landowner, its successors and assigns, copies of the inspection findings and a directive to commence with the maintenance or repairs if necessary.
- 6. In the event the Landowner, its successors and assigns, fails to maintain the stormwater management/BMP facilities in good working condition acceptable to the County, the County may enter upon the Property and take whatever steps necessary to correct deficiencies identified in the inspection report and to charge the costs of such repairs to the Landowner, its successors and assigns. This provision shall not be construed to allow the County to erect any structure of permanent nature on the land of the Landowner outside of the easement for the stormwater management/BMP facilities. It is expressly understood and agreed that the County is under no obligation to routinely maintain or repair said facilities, and in no event shall this Agreement be construed to impose any such obligation on the County.
- 7. The Landowner, its successors and assigns, will perform the work necessary to comply with the attached maintenance schedule, including sediment removal, and as otherwise required to keep these facilities in good working order as appropriate.
- 8. In the event the County pursuant to this Agreement, performs work of any nature, or expends any funds in performance of said work for labor, use of equipment, supplies, materials, and the like, the Landowner, its successors and assigns, shall reimburse the County upon demand, within thirty (30) days of receipt thereof for all actual costs incurred by the County hereunder.
- 9. This Agreement imposes no liability of any kind whatsoever on the County and the Landowner agrees to hold the County harmless from any liability in the event the stormwater

9/11/07 14A-4 MAINTENANCE

MAINTENANCE OF STORMWATER MANAGEMENT FACILITIES APPENDIX 14A

management/BMP facilities fail to operate properly.

10. This Agreement shall be recorded among the land records of Roanoke County, Virginia, and shall constitute a covenant running with the land, and shall be binding on the Landowner, its administrators, executors, assigns, heirs and any other successors in interests, including any homeowners association.

MAINTENANCE OF STORMWATER MANAGEMENT FACILITIES APPENDIX 14A

WITNESS the following signa	atures and seals:			
Company/C	Corporation/Partnership Name	(Seal)		
By:				
(Type Name)				
	(Type Title)			
STATE OF				
CITY / COUNTY OF				
The foregoing Agreement,20,by	was acknowledged before m			
	NOTARY PUBLIC			
	My Commission Expires:			
COUNTY	OF ROANOKE, VIRGINIA			
By:				
	(Type Name)			
	(Type Title)			
STATE OF				
CITY / COUNTY OF				
The foregoing Agreement	was acknowledged before m		_ day _	of
	NOTARY PUBLIC			
Approved as to Form:	My Commission Expires:			
County Attorney	Date			

STORMWATER MANAGEMENT BMP FACILITIES MAINTENANCE SCHEDULE

Map/Parcel Identification Number	er:
ed Book/Page Number:	
t of BMP Types and Number of Fa	
(Type of BMP)	(Number of Facilities of Listed Type)

PROVIDE COMPLETE MAINTENANCE SCHEDULE FOR EACH BMP TYPE. IF NECESSARY EXPAND TYPICAL SCHEDULE.

MAINTENANCE OF STORMWATER MANAGEMENT FACILITIES APPENDIX 14A

BMP Type:		
Required Action	Maintenance Objective	Frequency of Action
Inspections		
Vegetation		
Management		
Slope, Embankment,		
and Outlet Stabilization		
Debris and Litter		
Control		
Mechanical		
Components		
Insect Control		
Access Road and Area Maintenance		
Sediment and		
Pollutant Removal		
Component Repair and Replacement		

Other

APPENDIX 14B

MAINTENANCE OF STORMWATER MANAGEMENT SYSTEMS

Maintaining Your BMP A Guidebook for Private Owners and Operators in Northern Virginia

A Project of the Northern Virginia Planning District Commission Division of Environmental Services February 2000

Maintaining Your BMP

A Guidebook for Private Owners and Operators in Northern Virginia



Types of BMPs • Maintenance Needs Overview • Who Should Carry Out
Maintenance • Inspecting Your BMP • Planning for BMP Maintenance Costs
BMP Resource Guide

A Project of the Northern Virginia Planning District Commission Division of Environmental Services February, 2000

COU 9/11/...



A Guidebook for Private Owners and Operators in Northern Virginia

BMPs, or Best Management Practices, are facilities designed to reduce the impacts of pollutants and increased stormwater on local streams caused by development. They are an essential part of the region's efforts to restore aquatic habitats in the Potomac River and the Chesapeake Bay. However, BMPs will fail prematurely if not properly maintained. Once a BMP fails, it will no longer perform its intended functions and it is often very expensive to replace.

Whether you are an individual property owner, a homeowners association representative, or a residential/commercial property manager, this Guidebook outlines basic maintenance and planning tasks that will help keep your BMP functioning properly.

Contents

BMP Resource Guide	Inside Front Cover
Do You Have a BMP?	3
Which Type of BMP Do You Have?	3
Are You Responsible for BMP Maintenan	nce?6
Maintenance Needs Overview	6
Routine Maintenance Needs	7
Non-Routine Maintenance Needs	10
Who Should Carry Out Maintenance?	
Inspecting Your BMP	14
Planning for BMP Maintenance Costs	
BMP Maintenance Quick Guides	20

THIS GUIDEBOOK IS NOT a set of rules and regulations or a manual that provides guidance on how to design or build a BMP.

1

As you read through this Guide...



A thoughtful BMP maintenance program will save money and time in the long run. Key points to remember as you read through this Guidebook include:

Identify Facility Characteristics and Maintenance Needs. Understand how your facility works and its specific maintenance needs. While this Guidebook includes general information on the maintenance needs of common BMPs, valuable information can also be gained by consulting with your local government.

Check Your Maintenance Agreement. If you have a BMP maintenance agreement with your local government, this document should be consulted often to determine your specific obligations.

Define Maintenance Tasks, Personnel, and **Equipment.** Defining maintenance tasks and who will undertake these tasks – along with establishing a regular inspection program - is the core of a successful BMP maintenance program.

Identify Costs and Allocate Resources. While routine maintenance costs can typically be predicted for an annual budget, some BMP maintenance tasks will require infrequent but considerable expenses. Non-routine expenses need to be identified, and a long-term fund allocation plan needs to be developed.

Involve the Community. Pollutants treated by your BMP are generated from surrounding yards, streets, and businesses. Implementing a pollution prevention program and educating neighbors on the purpose of the BMP is a cost effective way to prolong its life and to protect water quality.

Establish a Record Keeping Procedure. Establishing a record keeping procedure will help to define chronic maintenance problems and aid in future budget preparation. A periodic examination of maintenance practices will help identify potential problems early.

Like many technical professions, the world of BMP maintenance has a language all its own. The following is a glossary of common BMP terms.

- Access Systems. Measures and devices that provide access to facility components by maintenance personnel and equipment.
- **Aeration**. The process of introducing air space
- Anti-vortex Device. A device that promotes the settling of pollutants by preventing a whirlpool from occurring at the outlet device.
- Berm. An elongated ridge of material that is used to hold or direct stormwater.
- **BMP.** Best Management Practice.
- Bypass System. A system which allows maintenance by temporarily diverting stormwater.
- Dam/Embankment. The wall or structural fill that impounds runoff in the facility. Emergency Outlet/Spillway. The structure that safely conveys overflows from the facility.
- Emergent Plants. An aquatic plant that is rooted in sediment but whose leaves are at or above the water surface.
- Filter Fabric/Geomembrane. A webbed fabric which serves to filter pollutants or to hold a
- filter medium such as gravel or sand in place. Impervious Cover. Any hard surface material
- that prevents water from sinking into the soil.

 Perimeter. The outward boundary of the BMP.

 Principal Outlet. The structure that controls
- and conveys the facility's outflow. **Pump System.** Electrical/mechanical
- components including pipework used to convey BMP discharge under pressure.
- Rip Rap. A layer or mound of large stones placed to prevent erosion.
- Riser. A vertical pipe extending from the bottom of a BMP that is used to control the rate of stormwater discharge.
- Side Slopes. Slopes at dams, embankments, spillways, and the facility perimeter.

 Swale. An elongated depression in the land
- used to channel runoff.
- SWM. Storm Water Management.
- Trash Rack. Device placed upstream of the
- principal outlet or drain to intercept debris.

 Trickle Ditch/Low Flow System. Measures that convey low and dry weather inflows to the principle outlet without detention.
- Vegetative Cover. Vegetation used to stabilize surfaces and/or provide stormwater treatment.

2

Do You Have a BMP?



Do you have a BMP? Simple depressions, ponds, or ditches that you see every day may actually be engineered facilities designed to improve water quality and reduce flooding.

BMP, which is short for Best Management Practice, is the term used to describe a structure or facility that reduces the impacts of development on water quality and aquatic habitats. Pollutants caused by urban development (called nonpoint source pollution) include sediment, nutrients, motor oil, lawn care products, and anything else that can wash from roof tops, driveways, parking lots, lawns, and streets during a storm event. In addition, urban stormwater drainage patterns, which do not allow stormwater to infiltrate into the ground, can often result in flooding.

BMPs operate by temporarily detaining or slowing stormwater, after which a number of pollutant removal mechanisms are employed (see pages 4 and 5 for additional details). Some BMPs, such as sand filters, can be located completely underground, making their presence difficult to detect. However, most BMPs are located on the surface. The two most common BMPs in Northern Virginia – dry ponds and wet ponds – are pictured to the right.

If you do have a BMP, you are not alone. A variety of laws, including the Virginia Chesa-



TYPICAL DRY POND



TYPICAL WET POND

peake Bay Preservation Act, the Virginia Stormwater Management Act, and the federal Clean Water Act, encourage or require the control of urban pollutants. As such, maintaining your BMP is an important part of Northern Virginia's environmental protection efforts.

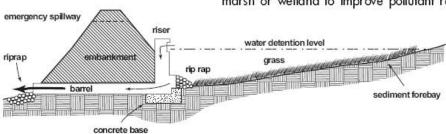


There are many types of BMPs. Taking a moment to understand what kind of BMP you have and how it works will help you to better plan for its maintenance needs.

EXTENDED DETENTION BASINS - "DRY PONDS" [FIG1] Dry ponds retain water for a specified period of time (usually 48 hours) after a storm. Water is impounded temporarily to allow many of the pollut-

3

ants to settle to the bottom. The impounded water is discharged through an outlet that provides for prolonged release. These are the most common BMPs in Northern Virginia. Most dry ponds do not contain a permanent pool of water, and no water will remain if it is functioning properly. Some dry ponds, however, incorporate a shallow marsh or wetland to improve pollutant removal. These



facilities are known as extended detention wetland basins or two stage detention ponds. It is important to determine whether standing water is by design or a sign that maintenance is required.

earth grass filter area earth aggregate rook

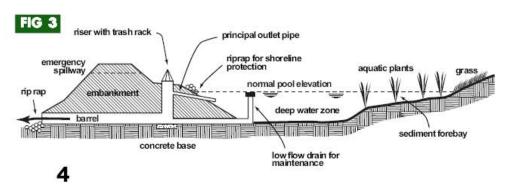
FIG 1

FIG 2

INFILTRATION TRENCHES [FIG 2] Infiltration trenches are gravel-filled excavations that temporarily store stormwater and allow it to sink into the underlying soil. Stormwater can enter the facility in one of two ways. In a dispersed input facility, water from impervious surfaces is directed over a gently sloping grassed area to remove large particles that otherwise might clog the facility. In a concentrated input facility, runoff is transferred to the trench directly from curb inlets, gutters, and pipes.

RETENTION BASINS - "WET PONDS" [FIG 3] Wet ponds contain a permanent pool of water much like a lake. The wet pond is designed to hold a permanent pool, above which stormwater runoff is temporarily stored and released at a controlled rate. The release is regulated by an outlet similar to that employed in a dry pond. The advantages of a wet pond over a dry pond are higher pollutant removal

and less chance that pollutants will be resuspended during a storm. Wet ponds can also serve as an aesthetic or recreational amenity as well as a habitat for some wildlife. However, wet ponds pose a higher safety liability than other BMPs.



9/11/07

MAINTENANCE OF STORMWATER MANAGEMENT FACILITIES APPENDIX 14B

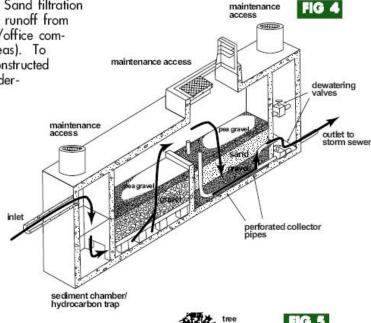
SAND FILTRATION SYSTEMS [FIG 4] Sand filtration systems (sand filters) are used to treat runoff from highly impervious settings (commercial/office complexes and high density residential areas). To save space, sand filters are usually constructed inside a concrete shell and placed underground. Sand filters work by slowly filtering stormwater through a layer of sand (and sometimes a sand/peat mix), and pollutants are removed when they become trapped between sand particles and other filter media. In some filters, microbes help remove pollutants through bio-chemical conversion.

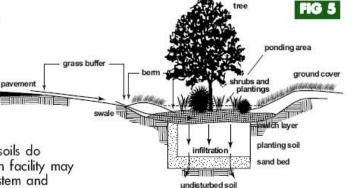
BKORETENTION FACILITIES – "RAIN GARDENS" [FIG 5] Bioretention facilities, or "rain gardens" as they are often called, are basins designed to mimic the conditions found on a mature forest floor. Configured to act as a sink and underlain with specific layers of soil, sand, and organic mulch, runoff is trapped and treated by vegetation and microbes. The facility is planted with specific types of vegetation, some of which are selected because of their ability to bind and convert pollutants to

biomass. In areas where the local soils do not support infiltration, a bioretention facility may be underlain by a sand filtration system and underdrain that carries treated water to a storm drain.

GRASSED SWALES [FIG 6] Grassed swales can be seen along many of Virginia's roadways, although they are not always designed to treat stormwater. Typically, grassed swales are concave, earthen conveyance systems designed to simply transfer runoff. As a water quality device, a grassed swale is constructed to allow stormwater to soak into the soil, and particles are trapped by the groundcover – usually turf grass. Many swales are constructed with berms (small dams made of earth, rock, or wood) to create temporary ponds that prevent erosion and help promote infiltration of stormwater into the soil.

If you don't recognize any of these BMPs, call your local government contact to find out what you have and whether it has special maintenance requirements.







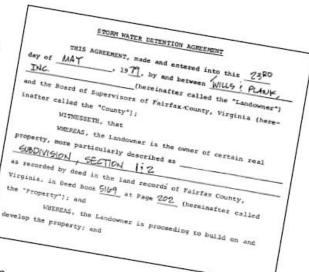
5

FIG 6

Are You Responsible for BMP Maintenance?



We are all responsible for protecting water quality. But are you responsible for the maintenance and upkeep of your BMP? Many Northern Virginia local governments will maintain stormwater management facilities in residential areas under specific conditions. However, if your community or business is subject to a BMP maintenance agreement, most likely you are the responsible party. It is important to check your maintenance agreement to identify your specific legal obligations although doing a little extra never hurts. If you are not sure who is responsible for maintenance, are unable to locate your maintenance agreement, or have questions about what your maintenance agreement means, refer to the BMP Resource Guide at the front of this Guidebook.



THE BOTTOM LINE. A maintenance agreement sets out your legal obligations.

Maintenance Needs Overview



A consistent maintenance program is the best way to ensure that a BMP will continue to perform its water quality functions. In general, a maintenance program should contain the components listed below.

- Regular Inspections
- Vegetation Management
- Embankment and Outlet Stabilization
- Debris and Litter Control
- Mechanical Components
- Insect Control
- Access Maintenance
- Overall Pond Maintenance
- Sediment/Pollutant Removal
- Components Replacement

Actual maintenance needs will obviously vary according to the specific facility and site conditions. The following are a few factors affecting type and frequency of maintenance that will be needed.

- Visibility of the Facility. The needs and preferences of the surrounding community will determine to a large extent the amount of maintenance for aesthetic purposes.
- Landscaping. Maintenance needs will vary considerably depending upon the types of vegetation used in landscaping. Rain gardens in particular will require special attention to vegetation management.



UNTIMELY DEMISE. Over half of BMPs fail in the first five years due to lack of proper maintenance.

■ Upstream Conditions. The condition of the watershed upstream of the facility can significantly impact the amount of sediment and other pollutants that a facility must man-

age. Erosion problems upstream can dramatically increase the amount of sediment entering the facility. Upstream commercial and recreational areas may also result in an increased need for litter removal.

A BMP maintenance program should also consider the following.

- Safety. Since BMPs often involve the impoundment of water, the safety of nearby residents or customers must be considered. This includes maintaining appropriate fencing and signage.
- Need for Professional Judgment. BMPs are water treatment facilities. While some maintenance can be undertaken by a non-professional, the judgment of a professional should be consulted regularly.
- Financing. The costs associated with non-routine BMP maintenance tasks can be considerable. A fund should be established to provide for the costs of long-term maintenance needs such as sediment removal.

Routine Maintenance Needs



Routine maintenance will keep your BMP functioning properly and will pay off in the long run by preventing unnecessary repairs. The following is an overview of the common routine maintenance needs of most BMPs.

REGULAR INSPECTIONS

Your local government will require a particular schedule of inspections for your BMP. In many instances, an annual or semi-annual inspection, depending on the facility, is required. It will also be necessary to conduct an inspection any time that the BMP's capacity has been surpassed. Some BMPs, such as sand filters, may require more frequent inspections. Additional information on who needs to carry out inspections is provided under *Inspecting Your BMP* on page 14.

VEGETATION MANAGEMENT

Most BMPs rely on vegetation to filter sediment from stormwater before it reaches the BMP and to prevent erosion of the banks and the bottom of the facility. Turf grass is the most common groundcover – although many BMPs use woody vegetation (rain gardens) and wetland plants (wet ponds) to increase pollutant removal.

The following is a quick reference of ways to help your vegetation stay healthy.

Mowing. Most grass is hardiest if it is maintained as an upland meadow, cut no shorter than 6 to 8 inches. If a more manicured look is desired, special attention to the health of the turf is needed. Grass should never be cut below 4 inches. Grass

on embankments should be cut at least twice during both growing seasons and once during the summer. Guidance documents are available to help set your blade at the appropriate height for the specific turf grass (see BMP Resource Guide).

- Pest and Weed Control. To reduce the amount of pollutants reaching the BMP, avoid overfertilization and excess pesticide use. Your local Virginia Cooperative Extension office (see BMP Resources Guide) can provide additional information.
- Removing Sediment Build-Up. Because vegetation surrounding a BMP is designed to trap sediment, it is likely to become

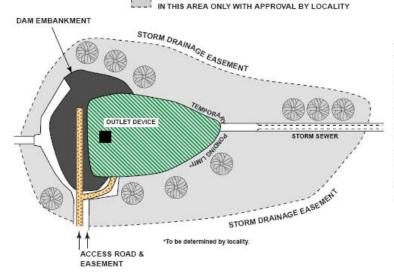


DESTABILIZING INFLUENCE. Trees on embankments and bottom areas will destabilize the BMP.

laden with sediment and bare spots may emerge. Bare areas should be vigorously raked, backfilled if needed, and covered with top soil. Disturbed areas should be seeded (a tall fescue grass seed is recommended) and mulched. Excess material should be taken off-site and can be used as a mulch or soil supplement. If the soil becomes compacted, it will require aeration by a landscape company.

- Unwanted Vegetation. Some vegetation is destructive to a BMP. Keeping dam and bottom areas free of deep-rooted vegetation (trees and bushes) is critical because roots can destabilize the structure. Consistent mowing and monitoring will control any unwanted vegetation.
- No Mow Zones. For wet ponds, a 10 foot un-maintained vegetated buffer around the perimeter of the facility (exclusive of the dam embankment) may be established to filter pollutants from adjacent properties and to help prevent shoreline erosion.

Activities that have the potential to damage vegetation or compact the soil should be avoided. What may seem like a harmless activity (sports activities, inappropriate landscaping, etc.) could take years off the life of your facility. Before altering vegetation in a BMP, contact your local government.



TREES AND OTHER VEGETATION ALLOWARLE

VEGETATION MANAGEMENT. Vegetation management is critical in areas immediately surrounding almost all BMPs. The accompanying figure shows critical management areas for wet and dry ponds. Woody vegetation should be avoided in all areas except where they will not affect structural components or maintenance access. Always check with your local government before planting.

BURY THE BURROWS. Fill animal burrows quickly to

prevent destabilization.

EMBANKMENT AND OUTLET STABILIZATION

A stable embankment is important to ensure that erosion does not contribute to water quality problems and that embankments are not breached – resulting in downstream flooding.

Maintaining a healthy vegetative cover and preventing the growth of deep-rooted (woody) vegetation on embankment areas is an important component of stabilization.

Animal burrows will also deteriorate the structural integrity of an embankment. Muskrats in particular will burrow tunnels up to 6 inches in diameter. Efforts should be made to control excessive animal burrowing, and existing burrows should be filled as soon as possible.

Outlet structures are particularly prone to undercutting and erosion. Unchecked, a small problem can easily result in the

need to replace the entire structure. A professional engineer should be consulted if sink holes, cracking, wet areas around the outlet pipe, pipe displacement, or rusting of the pipe are observed.

DEBRIS AND LITTER CONTROL

Regular removal of debris and litter can be expected to help in the following areas:

- reduce the chance of clogging in outlet structures and trash racks;
- prevent damage to vegetated areas;
- reduce mosquito breeding habitats;
- maintain facility appearance; and,
- reduce conditions for excessive algae growth.

Special attention should be given to the removal of floating debris which can clog inlet and outlet devices. If trash or dumping is particularly problematic, outreach to the local community can help (see *Involving the Whole Community*, page 12).

MECHANICAL COMPONENTS

Some BMPs have mechanical components that need periodic attention – valves, sluice gates, pumps, anti-vortex devices, fence gates, locks, and access hatches should be functional at all

times. This type of routine maintenance is best left to a BMP professional.

INSECT CONTROL

Mosquito and other insect breeding grounds can be created by ponded water. Though perceived as a significant nuisance, mosquitos are not as big a problem as is often thought, and there are ways to address the issue. The best control technique is to ensure that stagnant pools of water do not develop. For BMPs that have a permanent pool of water, this means the prompt removal of floatable debris. It may also be possible in larger wet ponds to main-tain a stock of fish that feed

on mosquito larvae. The Department of Game and Inland Fisheries can provide additional information on this management option (see *BMP Resource Guide*).

The development of a mosquito problem, particularly in dry ponds, infiltration trenches, and rain gardens, is usually an early indication

LITTER REMOVAL. Not only are litter and debris unsightly, they can clog BMP components and create conditions perfect for insects.



that there is a maintenance problem. In such cases, the infiltration capacity of the BMP needs to be increased or sediment needs to be removed.

ACCESS MAINTENANCE

Most BMPs are designed so that heavy equipment can safely and easily reach the facility for non-routine maintenance. Routine maintenance of these areas is particularly important since one never knows when emergency access will be needed. Maintenance includes removal of woody vegetation and upkeep of gravel areas.

OVERALL POND MAINTENANCE

An often overlooked aspect of maintenance, especially for wet ponds, is the need to ensure a healthy aquatic ecosystem. A healthy ecosystem should require little maintenance. An indicator of an unhealthy system is excessive algae growth or the proliferation of a single species of plant in the permanent pool of a wet pond. This may be caused by excess nutrients from fertilization practices (of a

landscape company or surrounding neighbors) or by excess sediment. Steps should be taken to reduce the nutrients at their source and to encourage the growth of more desirable aquatic and semi-aquatic vegetation in and around the permanent pool. The Department of Game and Inland Fisheries can provide additional information on overall pond maintenance practices (see BMP Resource Guide).

INVASION. An invasion of a single aquatic species (such as water chestnut), indicates an unhealthy aquatic system.



Non-Routine Maintenance Needs

The non-routine maintenance needs of a BMP, while infrequent, can be major undertakings and should always be performed by a professional. While tasks will vary by facility, they typically include sediment/pollutant removal and replacement of BMP components.

SEDIMENT/POLLUTANT REMOVAL

Since the primary purpose of a BMP is to remove sediment and other pollutants (which are usually attached to sediment) from stormwater, sediment will naturally accumulate in a BMP and eventually need to be removed. Facilities vary so dramatically in terms of removal requirements that there are no fast "rules of thumb" to guide responsible parties. For instance, dry ponds should be cleared of



REPAIR AND REPLACEMENT. The dam and outlet of a dry pond in the process of repair after failure.

sediment once a significant portion of the BMP volume (25-50%) has been filled. For wet ponds, a minimum water depth of approxi-

mately 3 feet is desirable. Sediment/pollutant removal needs of individual BMP types are discussed on pages 20 and 21.

Sediment and pollutants will need to be discarded. The best solution is to have an onsite area or a site adjacent to the facility (outside a floodplain) set aside for sediment. When sediment is stored near the facility, it is important to protect the stockpile against erosion. If onsite disposal is not an option, transportation and landfill tipping fees can greatly increase sediment removal costs. Once the sediment is removed, the facility should be quickly restabilized, either through revegetation or, in the case of a sand filter, replacement of sand and other filter media if necessary.

Finally, wet sediment is more difficult and expensive to remove than dry sediment. In some cases, the entire facility can be drained and allowed to dry so that heavy equipment can remove sediment from the bottom. In other cases, it may be necessary to remove sediment

from the shoreline or by hydraulic dredging from the surface. A permit may be required for removal and proper disposal of sediment. Contact your local government for assistance.

BMP COMPONENTS REPLACEMENT

Eventually, like most infrastructure, actual BMP components will need to be replaced. Components may include:

- inflow and outflow devices;
- trash racks and ani-vortex devices;
- valves, orifices, and aerators;
- concrete structures (such as the casing for a sand filter);
- pumps and switches;
- earthworks such as embankments and side slopes; and,
- mulches and vegetation.

While most BMPs will last for a long time with proper maintenance, a community or business should plan long in advance for replacing these facilities.

Who Should Carry Out Maintenance?

In determining who should carry out maintenance activities, safety, cost, and effectiveness need to be balanced.

Some activities can be undertaken effectively by a facility owner if desired. Maintenance tasks that are appropriate for a facility owner may include simple landscaping, education of those who are served by the facility, litter removal, and some routine maintenance.

While engaging a community or business in routine maintenance is a great way to educate people about the facility's purpose, it is strongly recommended that a professional landscaping company be hired for more difficult work. Mowing and handling a wheelbarrow can be dangerous on sloping embankments. Filling



COMMUNICATE. Sit down with your lawn care company to ensure that your BMP is being treated as a water quality protection device.

eroded areas, and soil disturbing activities, such as resodding and replanting vegetation, are also items that a professional landscaping firm might best manage. Trained personnel may be able to identify problems in their early stages of development when it is most cost effective to make repairs.

WORKING WITH LAWN CARE COMPANIES

Communicate to your lawn care company that your BMP is a water treatment system and requires special attention. While most companies have the ability to perform special maintenance, many will not unless specifically asked. Contact a company manager to discuss how their services can be tailored to help with BMP maintenance objectives.

- Communicate that the facility is a water quality protection device.
- Communicate specific instructions on mowing practices, for instance mowing at a higher level and perhaps not as frequently. Ask that heavy equipment be avoided where possible and particularly in vegetated pre-treatment areas.
- Communicate the need to keep sediment from building up in grassy areas and the need to keep the BMP facility clear of grass clippings (by the company and residents).
- Ask whether the company follows an integrated pest management (IPM) plan to minimize the application of pesticides and fertilizers. An IPM plan can include:
 - ✓ use of pesticides only as needed and only on trouble spots;
 - ✓ use of alternatives to pest controls or no pesticides; and/or,
 - policy of not applying chemicals when there is heavy rainfall in the forecast.

If that company cannot oblige, consider switching to a lawn care company that will.

INVOLVING THE WHOLE COMMUNITY

Even if day-to-day maintenance is left to a professional, involving the entire community in certain BMP maintenance activities is a cost-effective way to prolong the life-span of the facility and to prevent pollution. Involving the community can take the form of BMP clean-up days or community education.

In many instances, people are not aware of the cumulative effects of small acts of pollution on local water quality. Others are not aware that their activities contribute to pollution at all. Through public education, people are made aware of how their actions impact water quality, and they become vested in protecting their environment. As your business or commu-

nity considers developing a public education program, consider the following questions.

- What pollution problems need to be addressed? Is litter a problem? Does the BMP have an oil sheen, or has animal waste created problems?
- What activity or activities are responsible for the pollution? Is the oil coming from automobile leakage? Do residents routinely repair automobiles on community streets?



GET NEIGHBORS INVOLVED. A community BMP clean-up day will help people to understand your facility's purpose.

- Who can help implement a community education program? Can a local Boy/Girl Scout troop, chamber of commerce, school, or environmental group be used?
- How will the message reach the targeted community? Possibilities include community meetings, bulletin boards, local newspapers, signage, assistance from the locality, pamphlets, field days, etc.
- How can alternatives to pollution generating activities be encouraged? Find out where used oil and antifreeze recycling stations are located, organize a hazardous household waste day, find out if public trash cans are an option.

Popular programs that the community may wish to consider include:

- storm drain stenciling;
- education on proper pet waste disposal, lawn and garden care, and automotive care; and,
- finding and sharing information on recycling of used motor oil and antifreeze.

A BMP maintenance day is another way to involve the community. Activities that are appropriate for communities to perform in such an event on a periodic basis include:

- removal of debris and litter;
- seeding of bare spots; and,
- landscaping in areas other than the embankments (wildflowers, etc.).

INVOLVE THE COMMUNITY. A BMP maintenance day can help to draw attention to water quality in urban areas. There are a number of resources available to help educate people on ways to protect the environment.

Join Your Neighbors for a BMP Clean Up Day!!

What's a BMP? A BMP, or Best Management Practice, is a facility designed to trap pollutants from our neighborhood before entering Blissful Creek. Blissful Community's BMP is located at the corner of Nice Street and Friendly Court. Keeping our BMP free of debris will help to ensure that it continues to protect downstream aquatic life from harm and to keep our drinking water clean!

Saturday, September 18, 1999 9:00 AM at the Community Pool

Coffee, juice, and doughnuts will be served. Wear durable shoes, gloves, and work clothes.

Even if you can't make it, there are many simple things you can do to protect our community's water quality. Following the suggestions in the attached brochure can help!

Call Concerned Citizen at 555-5252 for more information.



Inspecting Your BMP



Inspecting your BMP allows you to detect problems early and to avoid long term problems. It is also usually a requirement of your maintenance agreement. Inspection requirements vary from jurisdiction to jurisdiction depending on the specific BMP. Some sand filtration systems require monthly inspections while other BMPs can be inspected on a yearly basis. Some localities provide inspections of all facilities while others require that the responsible party arrange for an inspection and send the results for confirmation. Your local government should be contacted to determine specific requirements and if you need help in selecting a qualified inspector.



INSPECTIONS. Regular inspections will save headaches and money.

It is unlikely that your lawn care or landscaping company has the know-how or experience to perform a proper, comprehensive BMP inspection. A professional (engineer, landscape architect, surveyor, etc.), or someone who has had appropriate training, should be hired to perform inspections. Since there is no "BMP inspection" listing in the telephone book, call your local government for advice on who to contact and how.

SELF EVALUATION AND WHEN TO CALL A PROFESSIONAL

The development of problems may not coincide with a visit from an inspector – particularly if there are out of the ordinary circumstances. Communities and businesses are encouraged to perform frequent self inspections. It is useful to have an original site plan on hand to help orient yourself. A self inspection should be able to check for:

- unexpected ponding;
- health of vegetation or growth of unwanted vegetation;
- obstructions of the inlet or outlet;
- excessive erosion or sedimentation;
- signs of dumping or pollutants other than sediment;
- cracking or settling of the BMP's structural components;
- wetness on the downstream side of the dam (indicating seepage);
- low spots or sinkholes in bottom areas;
- deterioration of pipes;
- condition of the emergency spillway;
- condition of fences;
- shore erosion;
- stability of the side-slopes and downstream channel conditions; and,
- signs of vandalism.

Inspection of underground systems such as sand filtration systems or infiltration trenches are obviously more difficult. A non-professional should never enter confined spaces meant for maintenance personnel. However, the facility owner should look for:

- water remaining in the system longer than design draw down time;
- obvious signs of excessive sediment build up or debris around the facility; and,
- signs of disturbance of manholes or damage to the structure caused by vehicles or settling.

Depending on the problem, either bring it to the attention of your landscape company or contact a professional BMP inspector.

Sample Self Inspection Checklist



STRUCTURAL INTEGRITY

Yes No N/A
Does the facility show signs of settling,
cracking, bulging, misalignment, or other
structural deterioration?

Yes No N/A
Do embankments, emergency spillways, side slopes, or inlet/outlet structures show signs of excessive erosion?

Yes No N/A
Is the outlet pipe damaged or otherwise not functioning properly?

Yes No N/A
Do impoundment and inlet areas show erosion, low spots, or lack of stabilization?

Yes No N/A
Are trees or saplings present on the embankment?

Yes No N/A
Are animal burrows present?

Are contributing areas unstabilized with evidence of erosion?

Yes No N/A
Do grassed areas require mowing and/
or are clippings building up?

WORKING CONDITIONS

Yes No N/A
Does the depth of sediment or other
factors suggest a loss of storage volume?

Yes No N/A
Is there standing water in inappropriate areas?

Yes No N/A
Is there an accumulation of floating debris and/or trash?

OTHER INSPECTION ITEMS

Yes No N/A
Is there evidence of encroachments or improper use of impounded areas?

Yes No N/A
Are there signs of vandalism?

Yes No N/A
Do the fence, gate, lock, or other safety devices need repair?

Yes No N/A
Is there excessive algae growth, or has one type of vegetation taken over the facility?

Yes No N/A
Is there evidence of oil, grease, or other automotive fluids entering and clogging the facility?

Yes No N/A
In rain garden BMPs, is there evidence of soil erosion, does mulch cover the entire area, are specified number and types of plants still in place, or is there evidence of disease or plant stress from inadequate or too much watering?

OTHER OBSERVATIONS

_		
_		

A yes answer to any of these items should result in corrective action or a call to a professional inspector.

Planning for BMP Maintenance Costs



BMP maintenance costs can be divided into routine and non-routine. Routine costs can usually be predicted for an annual budget and will range from 4% of original capital costs per year for a dry pond to 9% of original capital costs per year for an infiltration trench. A general rule of thumb is that annual maintenance will run from \$100 per acre for minimal maintenance including mowing to \$500 per acre for more intensive maintenance including mowing, weed

Non-routine costs, however, can be considerable over the long run, especially when considering the possibility of eventual BMP replacement.

control, fertilization, debris removal, etc.

To lessen the immediate financial impact of non-routine costs, it is advised that a BMP maintenance fund, with annual contributions, be established.

As an example, for dry ponds, which need to have sediment removed once every 2 to 10 years, 10% to 50% of anticipated dredging costs should be collected annually. In addition, the average dry pond has a life expectancy of 20 to 50 years. A separate fund that collects 2% to 5% a year should be established for replacement. Anticipated interest may be used to offset the effects of inflation.

ESTIMATING AND PLANNING FOR NON-ROUTINE COSTS OF YOUR BMP

Costs for non-routine maintenance of BMPs are highly specific and will vary depending upon the type, size, and depth of the facility, the volume of the sediment trapped in the BMP, the accessibility of the BMP, and whether or not on-site disposal of the sediment is possible. The primary non-routine costs are sediment/pollutant removal and BMP renovation/reconstruction. The following sections provide

information on sediment/pollution removal costs for (1) wet ponds and dry ponds, (2) sand filters, (3) infiltration trenches and rain gardens, and (4) grassed swales. General information is also presented on planning for BMP renovation/replacement.

REOCCURRENCE OF NON-ROUTINE COSTS

ВМР	Sediment Removal Frequency	Facility Life-span
Wet Pond Dry Pond Infiltration Trench Rain Garden Grassed Swale Sand Filter	5 to 15 years 2 to 10 years As needed 5+ years As needed Every 6 months or as required	20 to 50 years 20 to 50 years 10 years Indefinite Indefinite 20 to 50 years

WET AND DRY POND POLLUTANT REMOVAL COSTS

In general, both wet and dry pond pollutant removal costs are similar unless otherwise noted. The chart on page 17 show the ranges of costs associated with sediment removal for various sized wet and dry ponds. The last column is blank and can be used to estimate costs for your particular facility.

Mobilization and Demobilization. One of the larger fixed costs in dredging a BMP facility is mobilization and demobilization of the machinery. Large wet ponds will often require a waterborne operation during which an excavator or a crane must be

mounted to a floating barge and moved into position. The cost associated with such an operation is usually around \$10,000. For smaller ponds, larger ponds that can be drained or dredged from the shore, and extended detention basins, a perimeter or dry operation will usually suffice. In this case, a backhoe, truck equipment, or crane may be used to scoop out the sediment. The costs of mobilizing and demobilizing for this type of operation will range from between \$1,000 and \$7,000. Additional costs for the construction and restoration of access roads for trucks and heavy equipment may be required if not already provided.

■ Dredging. The cost of dredging a BMP depends on the volume of sediment removed. The cost (expressed by cubic yard) is largely influenced by the depth of the water and the distance between the excavation area and the "staging area" where sediment is transferred to trucks for re-

moval. Another consideration is whether equipment can easily access the BMP bottom. The following equation can be used to estimate the volume of sediment in cubic yards.

```
surface area ____ (acres) * depth of sediment ____ (feet) * 43,560 = ____ cubic feet ___ / 27 = ___ cubic yards.
```

■ Disposal. The primary determinant of disposal costs is whether on-site disposal is an option. If on-site disposal is not available, then landfill and transportation costs are an issue. Dumping at a landfill at current prices (1999) is estimated at \$47 per cubic yard (\$37 for dumping and \$10 for transportation depending on the dump location, mileage, and hourly charges).

Sample	Wet and I	Dry Pond S	Sediment 1	Removal C	
Component	Surface Area .25 acre Low High	Surface Area 1 acre Low High	Surface Area 2 acres Low High	Surface Area 10 acres Low High	Work Space acres Low High
Mobilization/ Demobilization/ Access Road	\$1,000 \$2,500	\$3,000 \$5,000	\$5,000 \$7,000	\$5,000 \$10,000	
Dredging*	\$1,613 \$3,025 (\$8/cy) (\$15/cy)	\$12,090 \$16,120 (\$15/cy) (\$20/cy)	\$24,195 \$32,260 (\$15/cy) (\$20/cy)	\$120,990 \$161,320 (\$15/cy) (\$20/cy)	
Disposal (Onsite/Offsite)	\$1,008 \$9,478 (\$5/cy) (\$47/cy)	\$4,030 \$37,882 (\$5/cy) (\$47/cy)	\$8,065 \$78,811 (\$5/cy) (\$47/cy)	\$40,330 \$379,102 (\$5/cy) (\$47/cy)	
Total Cost	\$3,621 \$15,003	\$19,120 \$59,002	\$37,260 \$118,071	\$166,320\$550,422	
Typical Equipment	Backhoe	Truck Equipment (1) Loader/Dozer (2) Crane Dragline or Clambucket			

*Dredging calculations assume a sediment accumulation of 6 inches. Costs will vary according to sediment depth. Estimated costs also assume that the facility is drained and the silt is dewatered in place.

By adding the likely costs of these three components in a dredging activity, one can establish a range in which an owner can expect to pay for sediment/pollutant removal.

INFILTRATION TRENCH AND RAIN GARDEN POLLUTANT REMOVAL COSTS

Infiltration-dependent BMPs, including infiltration trenches and rain gardens, require maintenance based upon findings of frequent inspections. For a typical infiltration trench, the major cost will be to remove the top 6 to 12 inches of gravel and to replace the filter cloth sediment barrier. The cost of such an operation is generally between \$1,500 to \$2,000.

Because rain gardens rely on a special mixture of soils for their operation, non-routine removal of sediments and replacement of some level of soil will be required periodically. The cost associated with such an operation is generally from between \$1,500 to \$2,000 depending upon the size and complexity of the facility.

Because the cost of infiltration trench and rain garden maintenance will vary depending on the frequency of maintenance, the owner should consult a local government representative to determine an appropriate funding level.

SAND FILTER POLLUTANT REMOVAL COSTS

The most common pollutant removal cost of a sand filter is to remove the top filter cloth (if applicable) and to remove/replace the filter gravel. The cost, expressed as dollar per impervious acre (that is, parking lots, roadways, and rooftops draining to the facility), is generally \$1,500 to \$2,000. Most sand filters only serve a few acres of land.

The frequency of filter maintenance largely depends on the type of BMP. A D.C. Sand Filter will require that the carbon trap be pumped and refilled every six months (\$500 to \$700) and the filter cloth and gravel be removed and replaced every 3 to 5 years (\$1,500 to \$2,000 per impervious acre served). An Austin Sand Filter, which is more commonly used in residential areas, may only need to be cleaned when a semi-annual inspection reveals that it is necessary.

If an oil sheen is present in the facility, the owner will be required to have the oil removed by a qualified oil recycler. Other expenses, such as removal of trash and hydrocarbons from water traps, may also be required.

Again, the owner should consult a local government representative to determine an appropriate funding level.

GRASSED SWALE POLLUTANT REMOVAL COSTS

Unlike other BMPs, grassed swales will last an indefinite period of time given proper maintenance. The primary non-routine maintenance cost associated with grassed swales is to remove accumulated sediments, to replace check dams (often constructed of earth, riprap, or wood), and to reseed. Such an operation should need to be performed only once every two years. When the grassed swale is on highway right-of-way, this type of activity may be covered through State maintenance. To find out if the swale is on State property, call the Virginia Department of Transportation at (703) 383-VDOT.

PLANNING FOR THE RECONSTRUCTION/ RENOVATION OF YOUR BMP

Like all infrastructure, including highways, bridges, schools, etc., BMPs have a life-span. For instance, most infiltration trenches will need to be completely renovated every 10 years. Most BMPs will last from 20 years to as many as 50 years if properly maintained. However, BMP requirements have been in place long enough (since the 1970s and 1980s) for many businesses and communities to have to grapple with the cost of reconstruction and/or renovation.

The reconstruction or renovation costs of any BMP are highly site specific and will be more or less expensive, adjusting for inflation, than the original cost of construction depending on access issues and the items needing replacement.

In all cases, it is recommended that the owner consult the local government to perform a BMP replacement fund study.

What Can You Do To Hold Down BMP Maintenance Costs?

Properly cared for, a BMP can work effectively for years without major maintenance costs. Abused, it can potentially be a continual financial drain. Businesses and homeowners associations can minimize costs and the potential liability of those responsible for BMP maintenance by promoting the following simple rules.

DO NOT!

- Dump used motor oil, antifreeze, or other oil and grease into storm inlets. This is a criminal offense.
- Dump grass clippings, leaves, soil, or trash of any kind into a BMP or a storm inlet. Leaves and grass clippings release bacteria, oxygen consuming materials, and nutrients. They will also clog BMP components.
- Dispose of pet wastes in the storm system including grassy areas near a BMP. Animal wastes contain disease causing bacteria and release oxygen consuming materials.
- Wash dirty vehicles on streets or driveways. Whatever comes off the car ends up in the BMP.
- Overfertilize the lawn. Whatever washes off the lawn or impervious areas (such as driveways or sidewalks) drains into the BMP and shortens its life-span.
- Leave bare areas unstabilized. Erosion from bare soil results in sediments that can clog a BMP.
- Dispose of left over paint or hazardous materials into the storm drain. These materials can kill BMP vegetation and aquatic life. Dumping is also a criminal offense.

DO!

- Keep properties, streets, and gutters free of trash, debris, and lawn clippings.
- Provide information to those who maintain their own automobiles on where to recycle oil and antifreeze.
- Encourage residents to take dirty vehicles to a commercial carwash or select a location where water does not enter a storm drain.
- Put a pan underneath your car if it is leaking to catch the fluids until it is repaired. Spread an absorbent such as cat litter to soak up drippings and dispose of properly.
- Educate residents on where to properly dispose of hazardous wastes, including oil and latex paints.
- Plan lawn care to minimize the use of chemicals and pesticides. Sweep paved surfaces and put the sweepings back on the lawn.
- Limit the amount of impervious surfaces. For patios, walkways, and landscaping, consider porous pavements such as bricks, interlocking blocks, or gravel.
- Incorporate native trees, shrubs, and groundcovers to help the water soak into the ground. Select species that need little fertilizer or pest control and are adapted to specific site conditions.
- Sweep up and dispose of ice melting chemical residues in the winter. This will protect grass and other landscaping plants.

ROUTINE MAINTENANCE

- Remove accumulated debris and litter, especially around inlet areas.
- Mow routinely, with heights preferably not less than 6 to 8 inches.
- √ Remove woody vegetation from all dam and embankment areas.
- Stabilize/revegetate side and bottom areas.
- Stabilize/revegetate contributing areas to reduce incoming sediments.
- Implement a pollution prevention program.

TIPS FOR WHEN NON-ROUTINE MAINTENANCE IS REQUIRED

Dry Ponds

- Standing water is visible in inappropriate areas after 48 hours.
- Insects and/or odor become problems. Wetland vegetation emerges lunless the facility is specifically designed with a marsh or wetland area).

■ Visible damage to the embankment (such as sinkholes) or mechanical components.

Wet Ponds

- Visible signs of sediment accumulation. Insects and/or odor become problems. Algae blooms occur in the summer
- months or ponded areas become dominated by a single aquatic plant.
- Visible damage to the embankment or mechanical components.

NON-ROUTINE MAINTENANCE

- ✓ Dethatch grass to remove accumulated sediments (less than every 2 years).
- ✓ Aerate compacted areas to promote infiltration (less than every 2 to 3 years).
 ✓ Remove accumulated sediment/pollutants
- (2 to 10 years for dry ponds; 5 to 15 years for wet ponds).

 Replace BMP components, reconstruct
- embankments and spillways (greater than 20 years if properly maintained).

ROUTINE MAINTENANCE

- √ Remove accumulated debris and litter from trench area.
- ✓ Mow routinely around trench with heights preferably not less than 6 to 8 inches.
- √ Remove woody vegetation and stabilize/ revegetate side areas.
- √ Stabilize/revegetate contributing areas to reduce incoming sediments.
- ✓ Implement a pollution prevention program.

TIPS FOR WHEN NON-ROUTINE MAINTENANCE IS REQUIRED

- Standing water is visible after 48 hours.
- Visible damage to the embankment or mechanical components.
- Apparent sealing of the top of the filter.

NON-ROUTINE MAINTENANCE

- ✓ Dethatch and aerate compacted grass areas (less than every 2 to 3 years).
- Remove and replace first 6 to 12 inches of gravel (as needed).
- √ Replace BMP (approx. every 10 years).

Grassed Swale Infiltration Trenc

ROUTINE MAINTENANCE

- Remove accumulated debris and litter.
- Mow routinely, with heights preferably not less than 6 to 8 inches.
- ✓ Remove woody vegetation and stabilize and revegetate side and bottom areas.
- √ Stabilize and revegetate contributing areas to reduce incoming sediments.
- ✓ Implement a pollution prevention program.

TIPS FOR WHEN NON-ROUTINE MAINTENANCE IS REQUIRED

- Standing water is visible after 48 hours.
- Insects and/or odor become problems.
- Wetland vegetation emerges. Visible erosion or undercutting of swale banks.

NON-ROUTINE MAINTENANCE

Remove accumulated sediment/pollutants (as needed).

Rain *G*arden

ROUTINE MAINTENANCE

- Limit confined space entry to professional maintenance personnel.
- ✓ Maintain appropriate safety precautions (locks and fences) and signage.
- Remove debris from inlet area.
- Ensure that contributing areas are not sources of debris or vehicle fluids.
- √ Keep any electrical components, such as pumps, in proper working order. Employ safe electrical practices and turn power off before maintenance.
- Stabilize/revegetate contributing areas to reduce incoming sediments.
- ✓ Implement a pollution prevention program.

TIPS FOR WHEN NON-ROUTINE MAINTENANCE IS REQUIRED

- There is a back-up of water in the filter.
- There is visible damage to mechanical components or concrete shell.
- Sink holes develop or sand deposition occurs.

NON-ROUTINE MAINTENANCE

- √ Remove accumulated sediment/pollutants.
- Replace sand and filter.
- Replace BMP components (greater than 20 years if properly maintained).

TROUBLESHOOTING

- Look for signs that plants are too wet including wilting, yellowing, ringed spots on leaves, and a soft or rotting base.
 If erosion is occurring at drainage paths,
- stabilize the erosion.
- If plants are dying, it may be necessary to choose plants more tolerant of drier/wetter conditions.
- If water is not dissipating, the facility is not functioning properly.

 Do not walk or mow in ponding greas.
- Do not drag electrical equipment through wet areas.

INSPECTION FREQUENCY

After or during each rainstorm, ensure that drainage paths are free from obstruction and that ponding dissipates. Water will pond longer in winter and early spring.

TIPS FOR WHEN NON-ROUTINE MAINTENANCE IS REQUIRED

- Standing water is consistently visible after one or two days.
- Invasive species take hold in the planting
- There is visible damage to BMP components such as berms or bottom areas.

NON-ROUTINE MAINTENANCE

- Aerate soil profile to increase infiltration
- capacity (as needed).
 Remove accumulated sediment/pollutants (2 to 10 years or as needed).

SEASONAL CARE

- Spring
 Prune deciduous trees and shrubs before
- leaves appear (usually early to mid-March). Prune flowering trees and shrubs after blossoming (usually early June).
- Divide ornamental grasses and perennials as soon as the soil becomes soft.

Summer

- During extended drought, water deeply in
- the morning every seven to ten days. Check trees and shrubs for signs of disease or insect pests. Plant diseases usually can be easily treated when detected early.
- Weed regularly, preferably by hand.

Fall

- Cut perennials back to the ground after the first frost and remove annuals.
- Plant new trees and shrubs as long as the soil temperature remains above 32 degrees.
- Mulch trees and shrubs to help condition the soil for spring and to protect roots.

Cut back ornamental grasses and remove clippings. No other maintenance is generally required.



7535 Little River Turnpike, Suite 100, Annandale, Virginia 22003 (703) 642-0700 FAX 642-5077 TDD (703) 642-8061 www.nvpdc.state.va.us

This Guide was developed by the Northern Virginia Planning District Commission with a grant from the Virginia Water Quality Improvement Fund. NVPDC is grateful to those who contributed their expertise and time to the completion of this document, including staff from the Chesopeake Bay Local Assistance Department, the Northern Virginia Soil and Water Conservation District, the Alexandria Department of Transportation and Environmental Services, and the Fairfax County Department of Public Works and Environmental Services. Many of the pidures are courtesy of the Fairfax County Maintenance and Stormwater Management Division. NVPDC takes full responsibility for the contents of this Guidebook.

Chapter 15 - Inspection and Enforcement

Inspection and enforcement can be divided into two distinct categories, during construction and post construction.

Construction inspection ensures that the storm drainage systems and stormwater management facilities are constructed and installed in accordance with the approved Stormwater Management Plan.

Inspection of erosion and sediment control during construction is regulated by the County of Roanoke Erosion and Sediment Control Ordinance.

Once construction is complete, a final inspection will be conducted, and as-built documentation will be submitted to show that the constructed project meets the requirements of the approved Stormwater Management Plan. At this point, the responsibility for the operation and maintenance of the storm drainage systems and stormwater management facilities is transferred from the permittee to the property owner or responsible party.

Where a project is constructed in phases, a final inspection shall be conducted of each completed phase as designated by the approved Stormwater Management Plan. The final inspection shall consist only of the phase being identified as complete.

After construction is complete, the property owner or responsible party is required to conduct periodic inspections and maintenance of the stormwater management facilities in accordance with the requirements of Chapter 14. Property owner inspections and maintenance activities must be documented and maintained. The County of Roanoke will conduct periodic post-construction compliance inspections of stormwater management facilities.

15.1 Construction Inspections

Construction of storm drainage systems and stormwater management facilities shall comply with the approved final Stormwater Management Plan. Any changes to the approved design require a resubmittal to the County of Roanoke for approval.

Inspections shall be performed by the permittee to ensure that construction conforms to the approved plans and specifications. Additional inspections will be performed by the County of Roanoke to confirm compliance.

15.1.1 Notifications to the County of Roanoke

The permittee shall notify the County of Roanoke 48 hours in advance of the start of construction and of the construction of critical components of a stormwater management facility. The following are examples of, but not limited to, critical components:

- Before the start of construction;
- Before installing a stormwater pond embankment;
- Before installing pond outlet structures;
- Before setting any concrete BMP structures, this does not include precast drop inlets or manholes;
- Before installing energy dissipation structures and any outlet structure into a jurisdictional stream (perennial or intermittent flow);
- Before installing any infiltration or bioretention BMP; or
- Any other key BMP component as determined by the County of Roanoke

15.1.2 Periodic Inspections

The permittee is responsible to perform adequate inspection of the construction activities to confirm that the site is in compliance with the Erosion and Sediment Control Ordinance requirements and that the construction of storm drainage systems and stormwater management facilities and BMPs are in conformance with the approved Stormwater Management Plan.

Upon completion of construction, the permittee must certify that the completed project is in accordance with the approved plans and specifications and must provide documentation of regular inspections sufficient to adequately support compliance. All permittee inspections shall be documented and written reports prepared that contain the following information:

- The date and location of the permittee inspection;
- Whether construction is in compliance with the approved Stormwater Management Plan;
- Variations from the approved construction specifications;
- Corrective actions that have been taken to correct previous violations;
- Any violations that exist or corrective actions that have been completed; and
- The name and signature of the person who performed the inspection.

The County of Roanoke shall conduct periodic inspections during construction. During the County inspection, the permittee will provide copies of all permittee inspections which have been conducted since the last County inspection.

If the County finds any violations, the permittee shall be notified in writing of the nature of the violation and of the required corrective actions. In conjunction, the County may issue an order requiring that all or part of the land disturbing activities permitted on the site be stopped until the specified corrective measures have been taken.

If the County of Roanoke determines that there is a repeated failure to comply with the approved plans and specifications, enforcement action may be taken.

A copy of a Stormwater Management Construction Inspection Checklist, for use by the permittee is included in Appendix 15A.

15.1.3 Final Inspection and As-Built Documentation

Prior to final acceptance of the project the permittee is required to submit to the County of Roanoke as-built documentation, confirming that the storm drainage systems and stormwater management facilities and practices that have been constructed conform to the approved Stormwater Management Plan. In addition, once the as-built documentation has been submitted, a final inspection will be conducted by the County of Roanoke to confirm that the as-built documentation conforms to the actual construction.

puilt documentation shall include the following:

- As-built survey conducted following construction, certified by a registered land surveyor or professional engineer. The survey shall include enough information to verify that storage capacities in ponds and other stormwater management structures are no less than the storage volume required by the approved Stormwater Management Plan. For retention and detention structures, a stage-storage summary table with design values and as-built values shall be included. The survey shall verify inverts and sizes of pipes, culverts, and outlet structures. Maximum tolerance shall be +/- 0.1 feet for structures and +/- 0.5 feet for finished grades.
- The permittee's inspection log records with copies of all inspection test results documenting compliance with the approved Stormwater Management Plan.
- Redline revision of approved Stormwater Management Plan. Place a check mark where design values agree with actual constructed values. For changed values enter the constructed value in red.
- Certification statement, signed by the permitee and a Professional Engineer or Professional Land Surveyor, registered in the Commonwealth of Virginia, indicating conformance with the approved Stormwater Management Plan.

If it is determined from the as-built documentation that the storm drainage systems and the stormwater management facilities have not been constructed in accordance with the approved Stormwater Management Plan, then corrective action will be taken to comply with the approved Plan or the permittee shall provide studies and information required by the County of Roanoke to demonstrate that the constructed systems will function equivalent to the approved Stormwater Management Plan. This includes meeting all flow, velocity, and regulatory requirements and that the approved elevation-storage requirement is maintained.

Once the as-built documentation has been accepted by the County of Roanoke, the permittee shall schedule a final inspection of the project site prior to final acceptance of the project by the County and the return of performance bonds or securities. The permittee shall provide 48 hour notice of a final inspection to the County of Roanoke.

15.2 Post-Construction Inspections and Maintenance

The property owner or responsible party is responsible for the proper operation, inspection, maintenance, and repair of stormwater management facilities, after the completion of construction, in accordance with the applicable maintenance agreement. All inspection, maintenance, and repair activities shall be documented. See Chapter 14 for additional information concerning maintenance and repair of stormwater management facilities.

The responsible party shall inspect and maintain stormwater management facilities at the frequencies listed in the Maintenance Agreement, or if they are not listed in the Maintenance Agreement, in accordance with Chapter 14.

In addition to the inspections performed by the responsible party, each stormwater management facility will be inspected periodically by the County of Roanoke.

In the event that the stormwater management facility has not been maintained and/or becomes a danger to public safety, public health, or the environment, the County of Roanoke shall notify the property owner, or responsible party, by registered or certified mail and issue a Notice of Violation. The Notice shall specify the measures needed to correct the situation and shall specify the time within which such measures must be completed. If the responsible party fails or refuses to meet the requirements of the maintenance agreement, the County of Roanoke, after reasonable notice, may apply a civil or criminal penalty and may correct a violation of the design standards or maintenance needs by performing all necessary work to place the facility in proper working condition, and recover the costs from the responsible party or property owner.

15.3 Records

Parties responsible for the operation and maintenance of a stormwater management facility shall make records of the installation and of all inspections, maintenance and repairs, and shall retain the records for at least five (5) years. These records shall be made available to the County of Roanoke upon request. See Appendix 15A for a blank Stormwater Management Facilities Inspection Report Form and a blank Stormwater Management Facilities Maintenance/Repair Report Form.

Each year, before December 31st, the property owner or responsible party shall mail to the County copies of the documentation for all inspection and maintenance activities that occurred during that year. This information shall be mailed to:

County of Roanoke Department of Community Development

5204 Bernard Drive

Roanoke, Virginia 24018

Attention: Development Review Coordinator (BMP Inspection and Maintenance Records)

15.4 Enforcement

Any activity that is commenced without an approved Stormwater Management Plan, or is conducted contrary to the approved Stormwater Management Plan, may be subject to the enforcement actions outlined in the County of Roanoke Stormwater Management Ordinance and the Virginia Stormwater Management Law.

A property owner or responsible party that does not properly maintain a stormwater management facility in accordance with the maintenance agreement may be subject to the enforcement actions outlined in the County of Roanoke Stormwater Management Ordinance and the Virginia Stormwater Management Law.

15.4.1 Notice of Violation

When a County of Roanoke inspection has noted that a construction activity or maintenance of a stormwater management facility is not in compliance with the approved **Stormwater Management Plan,** including all maintenance agreements, or the County of Roanoke Stormwater Management Ordinance, the County shall issue a written notice of violation delivered by registered or certified mail to the permittee or property owner.

The notice of violation shall include:

- The name and address of the responsible party;
- The address when available or a description of the building, structure or land upon which the violation is occurring;
- A statement specifying the nature of the violation;
- A description of the remedial measures necessary to correct the violation and a time schedule for the completion of such remedial action;
- A statement of the penalty or penalties that may be assessed against the person to whom the notice of violation is directed, should the remedial measures not be implemented;
- A statement that the determination of violation may be appealed by filing a written notice of appeal within 30 days of service of notice of violation.

15.4.2 Stop Work Orders

If a project site is under construction and receives a notice of violation, construction activities in the area where the work was found to be deficient in meeting the approved Stormwater Management Plan shall cease immediately.

The stop work order will be in effect until the County of Roanoke confirms that the land disturbing activity is in compliance with the approved Stormwater Management Plan. The permittee shall address the remedial measures published with the notice of violation within the time period specified. Upon completion of the remedial measures, the County of Roanoke shall inspect the work and authorize the permittee in writing that the stop work order has been removed and work may continue in that area of the project.

Failure to comply with a stop work order or with a notice of violation may result in the revocation of the permit and the violator shall be subject to the penalties set forth by the Stormwater Management Ordinance.

15.4.3 Penalties

Any person who willfully or negligently violates any provision of a local ordinance or program adopted by the locality under the authority of the Virginia Stormwater Management Program (VSMP) Permit Regulations (4 VAC 50-60) shall be guilty of a misdemeanor punishable by confinement in jail for not more than 12 months and a fine of not less than \$2,500 nor more than \$32,500, either or both.

Any person who knowingly makes a false statement in any form required to be submitted under the local ordinance requirements or renders inaccurate any monitoring device or method to be maintained to ensure compliance shall be guilty of a felony punishable by confinement in jail of not less than one year nor more than three years and a fine of not less than \$5,000 nor more than \$50,000.

Any defendant who is not an individual shall, upon conviction of a violation, be sentenced to pay a fine of not less than \$10,000.

Each day that a violation continues shall constitute a separate and distinct violation.

15.4.4 Restoration of Lands

Any violator may be required to restore land to its undisturbed condition in accordance with a notice of violation, stop work order, or permit requirements. In the event that restoration is not undertaken within the time specified in the notice, the County of Roanoke may take necessary corrective action, the cost of which shall be covered by the performance bond, or become a lien upon the property until paid, or both.

APPENDIX 15A

INSPECTION FORMS

Stormwater Management Construction Inspection Checklist

Stormwater Management Facilities Inspection Report Form

Stormwater Management Facilities Maintenance/Repair Report Form

Stormwater Management Construction Inspection Checklist

Inspector Name:			Inspection Date:			
Permittee's Name:			Permit Number:			
Site Address or Location	•					
Watershed:			Tax Map or Parcel ID No	•		
Reason for Inspection:						
☐ Routine Inspection		\Box Ir	ntensive Rainfall			
☐ Complaint		\square O	ther			
Disturbed Area (at time of Does the Site Require:			tormwater Pollution Preventi	on Dlan		
☐ SPCC Plan (oil stora	ige)		ther			
If required, are these pl	ans or perm	its available	on-site?			
	Eros	sion and Sec	liment Control			
		Acceptable Condition	Observations and Actions Required	Completion Date		
Silt Fence	Y 🗆 N 🗆	$Y \square N \square$				
Straw Bales	Y 🗆 N 🗆	$Y \square N \square$				
Inlet Protection	Y 🗆 N 🗆	$Y \square N \square$				
Stabilized Construction Y \(\subseteq \ \mathbf{N} \(\subseteq \) Y \(\subseteq \ \mathbf{N} \(\subseteq \)						
Sediment Trap/Basin	Y 🗆 N 🗆	$Y \square N \square$				
Check Dams	Y 🗆 N 🗆	$Y \square N \square$				
Seeding (Temporary or Final) $Y \square N \square Y \square Y$						
Other:	Y 🗆 N 🗆	$Y \square N \square$				
	$Y \square N \square$	$Y \square N \square$				
	$Y \square N \square$	$Y \square N \square$				
	V - N -	VINI				

Best Management Practices (BMPs)

Best Management Practice	Constructed as Approved?	Discrepancies and Corrections	Completion Date
	$Y \square N \square$		
	Y □ N □		
	Y□N□		
	$Y \square N \square$		
	$Y \square N \square$		
	Y□N□		
	$Y \square N \square$		

Stormwater Collection and Transport (Culverts, Storm Drains, and Inlets)

Item	Constructed	Discrepancies and Corrections	Completion
	as Approved?		Date
	$Y \square N \square$		
	Y □ N □		
	Y □ N □		
	Y □ N □		
	Y □ N □		
	Y □ N □		
	Y □ N □		
	Y □ N □		
Discharge Outfall from Development	Adequate channel:		
	$Y \square N \square$		

Signature of Inspector	Page 2 of 2
Signature of inspector	1 450 2 01 2

Stormwater Management BMP Inspection Checklist

Inspector Name:		Inspection Date:				
Site Address or Location: Watershed:				Tax Map or Parcel ID No:		
Type of Stormwater BMP or	Structu	re				
☐ Culvert			☐ Pond	(Permanent	Pool)	
☐ Inlet and Storm Drain				(Dry Pool)	,	
	Cantow	+i1a)		etention Basi		
☐ Open Channel (Vegetated/	Geolex	ille)				
☐ Open Channel (Concrete)			□ O1l/V	Vater Separa	tor	
☐ Other (Describe)						
	Chac	alrad	Main	tananaa		
Item Inspected	Chec Yes	No		tenance Not Rog	Observations and Remarks	
On an Channal and DMD English		l	Reqd.	Not Req.		
Open Channel and BMP Emb Does the structure show signs of	ankmer	its				
settling, cracking, bulging, or						
other structural deterioration?						
Do embankments, spillways, side						
slopes, or inlet/outlet structures						
show signs of erosion?]		
Is there evidence of animal						
burrows?						
Is there woody vegetation growth that may interfere with the flow or						
operation of the facility?						
Do vegetated areas need mowing						
or is there a build up of clipping						
that could clog the facility?						
Are there bare areas which need						
seeding or sodding? Is there standing water in						
inappropriate areas?						
Is there an accumulation of						
sediment, debris, or trash?						
Is there evidence of improper use						
of buffer areas, or construction or						
fill at channels or embankments						
which restrict flow or interfere with the proper operation?						
Is there evidence of oil or other						
pollutant spills?						

Page 1of 2

Itana In an arta d	Checked Maintenance		ntenance	Observations and Remodes	
Item Inspected	Yes	No	Reqd.	Not Req.	Observations and Remarks
Culverts and Storm Drains					
Is the culvert or storm drain filled more than 25% with debris, sediment, or trash?					
Is there evidence of structural failure of the culvert pipe?					
Is there evidence of erosion at the inlet and outlet of the culvert or at the storm drain inlet?					
Are there signs of settling, cracking, or misalignment of culverts, storm drain pipe, or concrete inlets?					
Stormwater Ponds (see also E	mbankı	ments)			
Is the emergency spillway clear of obstructions, debris, and vegetation?					
Is the outlet structure and pipe clean of debris and sediment, free of damage, and in working order?					
Is there an accumulation of debris, litter or trash?					
(For dry detention ponds) Is there standing water in the pond?					
(For wet ponds) Is their excessive algae growth or other vegetation?					
Is there evidence of oil or other pollutants in the pond?					
Is there erosion at the discharge point?					
Do any safety devices, fences, gates, or locks need repair?					
Other BMPs (Infiltration, San	d Filter	s, and	<u>Manufact</u>	ured Structur	res)
Is there sediment, debris, litter, oil, or trash that needs to be cleared for aesthetic or functional reasons?					
Is there standing water where there should not be standing water?					
Is there structural damage to concrete structures?					
Are there signs of erosion at entrance or exit?					
Are valves, sluice gates, and other mechanical devices operational?					
Signature of Inspector					Page 2 of 2

STORMWATER MANAGEMENT BMP FACILITIES INSPECTION REPORT FORM

<u>Inspection Requirements</u>: See the Stormwater Management BMP Facilities Maintenance Schedule for landowner's responsibilities for frequency of inspection and other requirements. This information is a part of the Maintenance Agreement that is recorded in the land records with the deed.

<u>Inspection Purpose</u>: To assure safe and proper functioning of the stormwater management BMP facilities and associated structures, by providing regular observations of their conditions and operation.

<u>Retention of Records:</u> All inspection/maintenance/repair documentation shall be retained by the landowner for a minimum of five (5) years.

<u>Submission of Records:</u> At the end of each year, by December 31st, mail all BMP inspection and maintenance documentation to:

County of Roanoke Department of Community Development 5204 Bernard Drive

Roanoke, Virginia 24018

Attention: Development Review Coordinator (BMP Inspection and Maintenance Records)

NAME OF BUSINESS OR LANDOWNER: _	
ADDRESS:	
INSPECTION DATE:	
PERFORMED BY:	
I LIGI ORNILD DI.	

Facility Management Checklist

The following items should be checked for each BMP:

- 1. Facility construction meets the requirements of the Roanoke County Stormwater Management Design Manual, where applicable, and is adequate for the intended function.
- 2. The facility has been maintained properly according to the requirements of the Recorded Maintenance Agreement, BMP Maintenance Schedule, and the Roanoke County Stormwater Management Design Manual.
- 3. The facility is functioning adequately.
- 4. There have been no changes to the site conditions or area that would require modification and/or replacement of the existing facilities.
- 5. Access to the facility is adequate and maintained.

STORMWATER MANAGEMENT BMP FACILITIES INSPECTION REPORT FORM

REFER TO THE RECORDED MAINTENANCE AGREEMENT BMP MAINTENANCE SCHEDULE FOR EACH BMP TYPE – COMPLETE SEPARATE FORM FOR EACH STORMWATER MANAGEMENT BMP FACILITY

BMP Type:	
BMP Location:	
Authorization	
Yes No	
□ □ Does the fa	cility comply adequately with all pertinent regulations and requirements?
Requirements to Meet	Compliance
Additional Observation	ns/Comments
	Sheet of

STORMWATER MANAGEMENT BMP FACILITIES MAINTENANCE/REPAIR REPORT FORM

	Refer to the site's Stormwater Management BMP Facilities Maintenance			
	sibilities for frequency of maintenance and other requirements. This ine of minimum maintenance requirements. Additional maintenance			
shall be performed as necessary for	or the proper functioning of Stormwater Management BMP facilities.			
This information is a part of the M	Maintenance Agreement that is recorded in the land records with the deed			
	To enable the proper long-term functioning of the stormwater of the Valley's water quality and prevent downstream flooding.			
Retention of Records: A minimum of five (5) years.	All inspection/maintenance/repair documentation shall be retained for a			
Submission of Records: A maintenance documentation to:	At the end of each year, by December 31 st , mail all BMP inspection and			
County of Roanoke Depart 5204 Bernard Drive	rtment of Community Development			
Roanoke, Virginia 24018 Attention: Development	Review Coordinator (BMP Inspection and Maintenance Records)			
NAME OF BUSINESS OR LA	ANDOWNER:			
ADDRESS:				
MAINTENANCE/REPAIR DA	ATE:			
PERFORMED BY:				
GENERAL COMMENTS:				
Sheet 1 of				

STORMWATER MANAGEMENT BMP FACILITIES MAINTENANCE/REPAIR REPORT FORM

REFER TO THE RECORDED MAINTENANCE AGREEMENT BMP MAINTENANCE SCHEDULE FOR EACH BMP TYPE – COMPLETE SEPARATE FORM FOR EACH STORMWATER MANAGEMENT BMP FACILITY

BMP Type:			
BMP Location:			
Routine Maintenance	<u>Performed</u>		
Repairs Performed			
<u>respuns i cirolinea</u>			
Remarks (Are addition	nal maintenance/repa	airs needed?):	
	Sheet	of	